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THE CEPHALOPODA OBTAINED BY THE HARVARD-HAVANA EXPEDITION OFF THE COAST OF CUBA IN 1938-39[1]

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ABSTRACT

The collections of cephalopods obtained by the ATLANTIS off the coasts of Cuba in 1938 and 1939 contained 253 specimens representing 21 genera and 25 species of which 1 genus and 4 species are new to science. All of the species are recorded together with their ranges and distribution. *Rossia antillensis* n. sp., *Heteroteuthis atlantis* n. sp., *Abralia redfieldi* n. sp., and *Tetracheledone spinicirrus* new genus and species, are described and figured. *Rossia brachyura* Verrill is figured for the first time. A key to all of the cephalopods definitely known to occur in Cuba is included.

INTRODUCTION

The collection of cephalopods obtained by the ATLANTIS off the coasts of Cuba in 1938 and 1939 contain 253 specimens representing 21 genera and 25 species of which 1 genus and 4 species are new to science.

It is interesting to note that over half of the species contained in this report are represented by only 1 specimen and 5 by only 2 specimens, while the remaining are well represented. Of these latter *Rossia* is by far the most common genus containing over half of the total number of cephalopods taken by the expedition. Of the remaining myopsid squid *Lolliguncula brevis, Doryteuthis plei,* and *Nectoteuthis pourtalesi* are the most numerous. The latter species, not reported since Verrill described it in 1883, is probably much more numerous than was formerly thought. The oegopsid squid are mainly represented by *Illex illecebrosus* and *Abralia veranyi.* The octopods, surprisingly, are best represented by two species, *Pteroctopus tetracirrhus* recently first recorded from the Western Atlantic by Voss (1954), and a new genus

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and species, *Tetracheledone spinicirrus,* of which 4 specimens were obtained.

The literature on Cuban cephalopods is very scarce. The first work appeared in 1841 by d'Orbigny as part of the larger work, "Histoire physique, politique et naturelle de l'Isle de Cuba," by Ramon de la Sagra, in which 16 species are recognized. Of these, 3 are synonyms of others in the list, and one is not native to the Western Atlantic.

In 1875 Arango published a list of cephalopods which apparently was copied from d'Orbigny's work. From that time until 1945 no cephalopod papers appeared with particular mention of Cuban species. In the latter year Pickford, in her revision of the littoral octopods of the Western Atlantic, listed *Octopus vulgaris* and *O. hummelincki* as found in Cuban waters. Lately, Dr. C. G. Aguayo has begun a publication listing all of the known species of mollusks from the island. The cephalopod section is as yet fragmentary since many of the genera and families have not been covered at the present time. The work is primarily a survey of previously published records.

Thanks to the kindness of C. G. Aguayo and Isabel Farfante the author has been privileged to examine several small collections of littoral cephalopods from Cuba in the course of several years, and this has confirmed the presence in Cuban waters of *Octopus briareus* and *Doryteuthis brasiliensis,* the latter collected this year (1954) from the vicinity of the Isle of Pines.

The author wishes to thank the Woods Hole Oceanographic Institution and the associate director, Dr. Alfred C. Redfield, for the financial aid in the form of a Research Fellowship to carry out this study. He also wishes to thank William J. Clench, Curator of Mollusks, Museum of Comparative Zoology, Harvard University for the loan of the collections for study and Harald A. Rehder, Curator of Mollusks, U. S. National Museum for permission to study certain comparative material in the collections of the latter institution and for facilities placed at his disposal during the summer of 1953.

Key to the Cephalopods of the Island of Cuba

The following artificial key is presented for the convenience of those interested in the cephalopods found in the waters of Cuba. In it are listed all of the species known to occur in the area, as well as those contained in the present report. Those not taken by the ATLANTIS, but recorded from other sources, are preceded by an aster-

isk. It is probable that many other species will be reported from Cuba with the increased activity in exploratory fisheries investigations. Thus the key alone should not be relied upon for final determinations.

I. Tentacles present; suckers stalked, usually provided with a horny ring or hooks (Decapoda).
  1. Eyes covered by a continuous membrane or open by a minute pore (Myopsida).
    2. An internal coiled, chambered shell.
      **Spirula spirula* Linnaeus
    2¹. Internal shell straight, feather-shaped, or absent.
      3. Adult small; body short and rounded posteriorly with round or ovate lateral fins; internal shell reduced or absent.
        4. Antero-ventral mantle margin strongly produced as a shelf nearly covering the funnel.
          5. Arm suckers raised on prominent pedicels, suckers extending to tips of all arms.
            Nectoteuthis pourtalesi Verrill
          5¹. Arm suckers normally stalked; distal half of second pair of arms blade-like, devoid of suckers.
            Heteroteuthis atlantis n. sp.
        4¹. Antero-ventral margin of mantle not strongly produced.
          5. Tentacular suckers in few rows (5-8), left dorsal arm of male hectocotylized.
            Rossia (Semirossia) sp.
          5¹. Tentacular suckers minute, in many rows; both dorsal arms of male hectocotylized.
            6. Suckers of sessile arms in 4 rows.
              Rossia brachyura Verrill
            6¹. Suckers of sessile arms in 2 rows, rectal papillae present.
              Rossia antillensis n. sp.
      3¹. Adult medium to large; body elongate, pointed posteriorly; fins unite posteriorly, internal shell feather-like.
        4. Fins marginal, extending nearly to anterior edge of mantle.
          Sepioteuthis sepioidea (Blain.)
        4¹. Fins terminal.
          5. Body short; fins terminal, rounded; female with spermatophore pad within mantle cavity.
            Lolliguncula brevis (Blain.)
          5¹. Body elongate; fins rhombic; spermatophore pad of female on lower lip of buccal membrane.
            6. Lateral edges of gladius straight, thickened, brownish.
              7. Mantle long, slender, width about ⅛ the length, lightly pigmented; ventral mantle surface streaked with reddish brown in the male.
                Doryteuthis plei (Blain.)
              7¹. Mantle stout, pigmented with purplish brown; no ventral streaks in the male.
                **Doryteuthis brasiliensis* (Blain.)
            6¹. Lateral edges of gladius curved, not thickened.
              **Loligo pealei* Lesueur
  1¹. Eyes not covered by a continuous membrane (Oegopsida).

2. Some of the suckers of the arms and/or tentacles converted into slender curved hooks.
   3. Arms with two rows of hooks.
      4. Fins drawn out to a point posteriorly, united; ventral surface of mantle with numerous rows of light organs.
         5. Arms with 2 rows of hooks; tentacular clubs with one row of hooks; 5 light organs on ventral surface of eyeball.
            6. 3 nearly equal size hooks on tentacular club; 1st, 3rd and 5th light organs on eyeball twice as large as 2nd and 4th, round.
               Abralia redfieldi n. sp.
            6¹. 4 hooks on tentacular club, proximal minute, 2nd largest, decreasing in size distally; 1st and 5th light organs on eyeball much larger than middle three, oval, the 5th often with a slight sinus in dorsal edge.
               Abralia veranyi (Rüppell)
         5¹. Both arms and tentacular club with 2 rows of hooks.
            **Thelidioteuthis alessandrini* Verany
      4¹. Fins lateral, reaching beyond the pointed posterior end of the the body, not united; no light organs on mantle.
         5. Arms with 2 rows of hooks; tentacular club with small number of hooks on ventral row.
            Pyroteuthis margaritifera aurantiaca Joubin
         5¹. Arms with two rows of hooks; no hooks on tentacular club.
            **Pterygioteuthis giardi* H. Fischer
   3¹. No hooks on arms.
      4. Body fleshy, stout, strongly colored with purplish brown; mantle with short point posteriorly; 2 rows of hooks and 2 rows of suckers on tentacular club; fins less than half the mantle length; animal small.
         **Onychia caribaea* (Lesueur)
      4¹. Body slender, with long drawn out posterior point; adults with fins longer than half the mantle length; 2 rows of hooks on tentacular club; animal medium to large.
         Onychoteuthis banksi (Leach)
2¹. No hooks on either arms or tentacles.
   3. Mantle locking at sides of funnel by means of locking grooves and ridges.
      4. Connective apparatus on tentacles indistinct; no folds or pockets in funnel groove.
         Illex illecebrosus (Lesueur)
      4¹. A distinct carpal cluster on tentacles; folds and side pockets in funnel groove.
         5. 0-2 cups on the tentacular stalk proximal to last cup of carpal cluster.
            **Sthenoteuthis pteropus* (Steenstrup)
         5¹. 4-7 cups on the tentacular stalk proximal to last cup of carpal cluster.
            **Sthenoteuthis bartrami* (Lesueur)
   3¹. Mantle fused to head at dorsum and on each side of the funnel.
      4. Body either covered with tubercles or with tubercles arranged in V-shaped lines at fusion of mantle and funnel.

5. Mantle smooth; V-shaped lines of tubercles at point of fusion of mantle and funnel.
Liocranchia reinhardti (Steenstrup)
5¹. Mantle completely covered with tubercles.
Cranchia scabra Leach
4¹. No tubercles on mantle.
Verrilliteuthis hyperborea (Steenstrup)

II. Tenetacles absent; 8 arms; suckers not stalked and without horny rings (Octopoda).
1. A single pair of fins present; cirri bordering suckers; deep water forms.
2. Body globular; fins large; arms long with simple velum.
3. Length of cirri bordering suckers about 2½ times the diameter of suckers.
Grimpoteuthis umbellata (Fischer)
3¹. Cirri bordering suckers no longer than the diameter of the suckers.
?*Grimpoteuthis meangensis* (Hoyle)
2¹. Body flattened; fins small and dorsal; arms nearly completely involved in the velum.
Opisthoteuthis agassizi Verrill
1¹. No fins.
2. Suckers in 2 rows.
3. Large and conspicuous aquiferous pores on head; dorsal arms of female connected by a broad velum.
**Tremoctopus violaceus* Delle Chiaje
3¹. No aquiferous pores on head; dorsal arms of female not connected by a broad velum.
4. Left third arm of male hectocotylized.
5. Male minute; female with dorsal arms with terminal expansions modified for secretion of an external shell or egg case; pelagic.
6. Shell of female small; keel broad, knobs few and large, broad auricular expansions.
Argonauta hians Solander
6¹. Shell large, keel narrow, knobs numerous and small, auricular expansions narrow.
Argonauta argo Linnaeus
5¹. No sexual dimorphism in size; female without an egg case; no terminal expansions of the dorsal arms; benthic.
6. A thickened fold or ridge surrounding the mantle; a single cirrus over each eye; surface covered with small papillae.
Scaeurgus unicirrhus d'Orbigny
6¹. No fold surrounding mantle; 2 cirri over each eye; skin smooth.
Pteroctopus tetracirrhus (Delle Chiaje)
4¹. Right third arm of male hectocotylized.
5. A persistent purple, blue or dark ring or ocellus at base of arms below eye on each side.
**Octopus hummelincki* Adam
5¹. No persistent ring or ocellus.
6. Arms large, long, and stout, especially the 3rd pair; gills 6-8; ligula index 3-4.

**Octopus briareus* Robson

6¹. Arms subequal except 1st pair which is much shorter; gills 7-11; ligula index below 2.5.

**Octopus vulgaris* Lamarck

2¹. Suckers in a single row.

3. Body gelatinous, soft, semi-transparent; planktonic, size small.

Eledonella pygmaea Verrill

3¹. Body firm, covered with coarse sharp tubercles; 2 large cirri over each eye; hectocotylus spade-shaped; benthic, moderate size.

Tetracheledone spinicirrus n. sp.

Systematic Discussion

Suborder *DECAPODA*

Division MYOPSIDA

Family SEPIOLIDAE Leach.

Rossia (Austrorossia) antillensis n. sp.

(Figures 1A-E)

Holotype. Male, Sta. 2987, 280-300 fms. off Sagua la Grande, March 13, 1938. MCZ Cat. No. 203976.

Paratype. Gravid female, Sta. 3485, 385 fms. off Cayo Romano, May 11, 1939. MCZ Cat. No. 203977.

This is a large species of *Rossia* with a rather flabby consistency (Figure 1A). The surface is smooth and densely covered dorsally, less so ventrally, with small purple and red chromatophores. The body is sacular, rounded posteriorly, with the dorsomedian border slightly projecting. The fins are large, 80 to 88.5 per cent of the mantle length, thick and fleshy, their anterior edges reaching to the anterior border of the mantle. The width across the fins is 163 to 200 per cent of the mantle length. The funnel is stout, tubular, free for half of its length. The locking apparatus is normal but strongly developed. The funnel organ is shown in Figure 1B.

The head is large. In the holotype the head width is 135 per cent of the mantle length; in the paratype the head was too distorted to obtain a useful measurement. The eyes are very large and conspicuous.

The arms are of medium length, in the order 2=3.4.1 or 3.4=2.1 with the suckers arranged distinctly in two rows. The suckers on the female are rather small, but the male holotype has suckers of medium size with those in the middle of the arms slightly enlarged. In the holotype the dorsal pair of arms is hectocotylized in the following manner. Proximally there are about six pairs of small suckers. These are followed by about six pairs of enlarged suckers which are about twice the diameter of the basal suckers. In the only male available, it is impossible to tell whether these are enlarged to the tip of the arm as

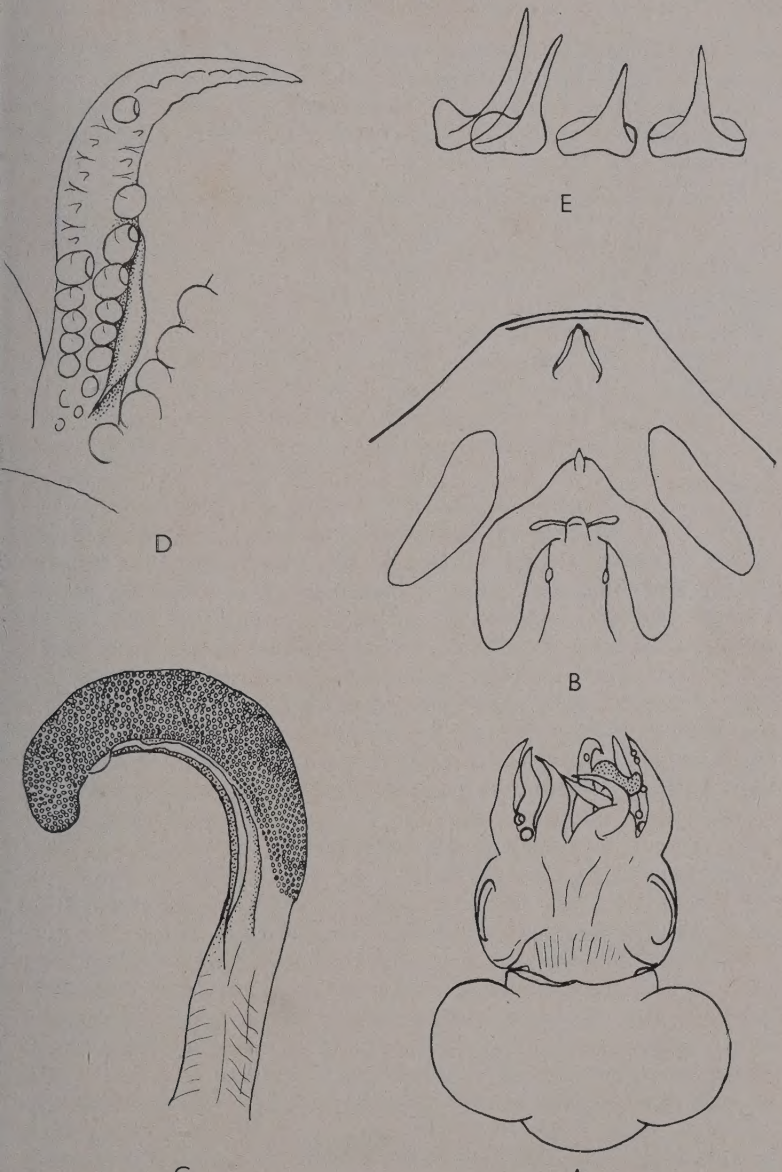

FIGURE 1. *Rossia* (*Austrorossia*) *antillensis* n. sp. A. Dorsal view, B. Funnel organ and rectal papillae, C. Left tentacle, D. Left dorsal arm showing hectocotylization, E. Radula.

the distal suckers are missing. Starting at the base of the third pair of suckers from the base of the arm is a thick, fleshy pad or fold on the outer or ventral side of the arm. This peculiar pad extends to the base of the eighth pair of suckers and is similar on both dorsal arms (Figure 1D).

Measurements (in mm) of two specimens of *Rossia antillensis* n. sp.

	Holotype	Paratype
Mantle length	43.0	72.0
Mantle width	40.0	——
Head width	47.5	47.0
Fin insertion	25.5	48.0
Fin length	31.0	57.5
Fin width	70.0	118.0
Arm length, 1st pair	33.0	71.5
2nd "	42.0	76.0
3rd "	42.0	87.5
4th "	37.0	77.0
Length tent. club	18.0	——

The tentacles (Figure 1C) are short, stout, the stalks generally oval in cross section, but squared on the ventral edge. The clubs are over half of the mantle from the proximal sucker to the tip, and are rounded instead of expanded, and no wider than the stalk. A well developed swimming membrane borders the dorsal edge from slightly below the suckers to within a millimeter of the distal end. The suckers are very minute, their total diameter about 0.25 mm, the diameter of the opening of the horny circle about 0.12 mm. The suckers are so small and crowded that it is not possible to distinguish the number of rows with certainty, but they appear to number about 30 to 40 rows.

The radula has seven rows of teeth, long and slender. The rhachidian teeth are long, slender with wide bases; first laterals slightly shorter and broader; second laterals long and slender, curving, longer than the rhachidian teeth; marginals long, strongly curving and arcuate, nearly twice as long as the rhachidian teeth (Figure 1E).

The spermatophores of the holotype had disintegrated within the outer capsule so that although they were measureable in total length, 12.0 mm and 34.2 per cent of the mantle length, none of the internal structures can be described. The eggs of the gravid female are oblong, somewhat reticulated and measured 7.0 x 4.5 mm.

A complete dissection of the internal anatomy was not considered advisable on the holotype and the paratype is in such a poor state of preservation that a dissection of it would have been useless. However,

an examination of the surface of the visceral mass disclosed that this species has a pair of papillae on the sides of the rectum as has been described for *R. mastigophora* Chun and *R. bipapillata* Sasaki.

Remarks. This species appears to be most closely comparable to Berry's *R. australis* for which he constructed the subgenus *Austrorossia* to accommodate both this species and *R. mastigophora* Chun. Whether this subgenus is valid seems to be open to question on several points. The very numerous and minute suckers of the tentacular club are also found in *R. brachyura,* which however, has four rows of suckers on the sessile arms. Some of the suckers of all of the arms are slightly enlarged or greatly so in the males of *Semirossia.* Also the nature of the pad on the dorsal pair of arms in the male is apparently lacking in *R. mastigophora* and unknown in *R. bipapillata,* but present in *R. australis* and *R. antillensis.* In most of these species there is a papillary organ on either side of the rectum. This is undescribed in *R. australis,* but may be present.

With the possible exception of the subgenus *Semirossia* there does not appear to be any homogeneity of characters within the genus *Rossia* which permits well characterized subgeneric division. However, on the basis of the composite characters listed by Berry (1918) it seems at present that the subgenus *Austrorossia* is comprised of four species: *R. australis, R. mastigophora, R. bipapillata,* and *R. antillensis.*

The present species may be separated from *R. mastigophora* and *R. australis* by the nature of the fleshy pad on the dorsal arms. Until the nature of the males of *R. bipapillata* is known this species cannot be separated except by the somewhat larger and less numerous tentacular suckers.

Rossia brachyura Verrill, 1883
(Figures 2A - C)

Rossia brachyura Verrill, 1883, p. 110.

Material. 1 female in alcohol, Sta. 2982B off Punta Alegre, Camaguey Prov. in 205 fms., otter trawl, March 11, 1938. MCZ Cat. No. 203978.

Verrill described this species from a single female of 18mm dorsal mantle length, taken by the BLAKE in 208 fms. off the island of St. Kitts. The present specimen is in an excellent state of preservation; only the end of the right tentacular club is missing. No other specimens are known.

As Verrill's description of this species is rather brief, the following

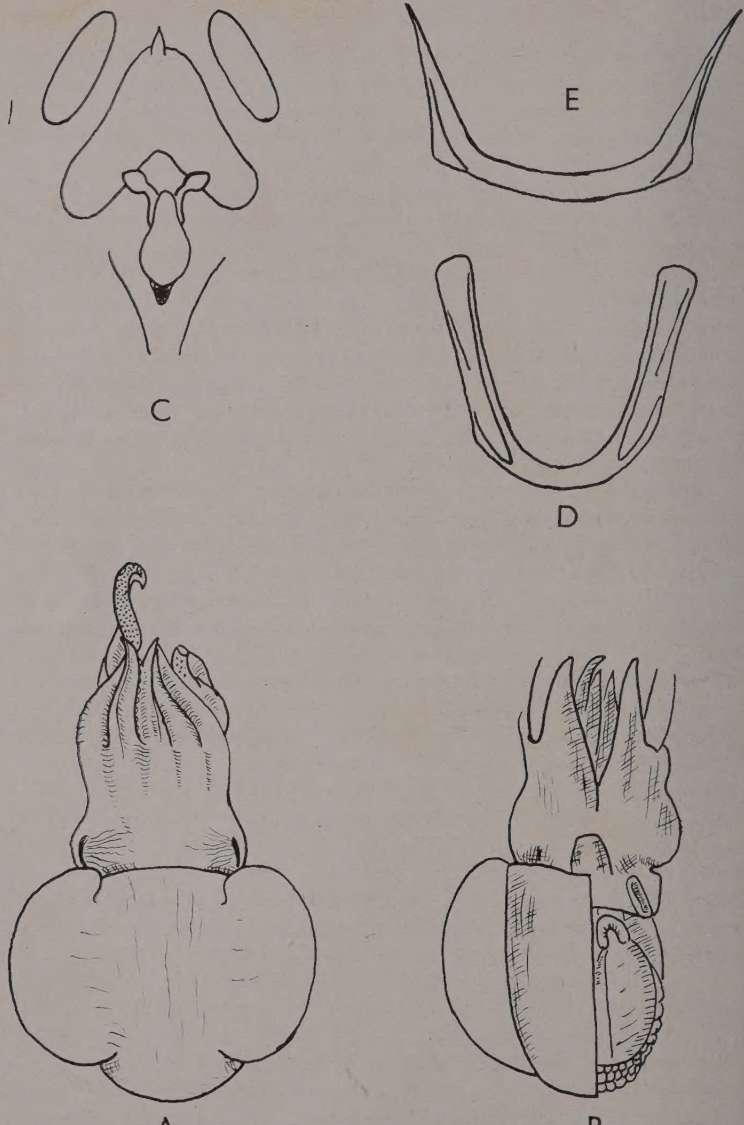

FIGURE 2. A-C *Rossia brachyura* Verrill. A. Dorsal view, B. Ventral view, mantle cavity open, C. Funnel organ. Figure 2D. Shell vestige of *Grimpoteuthis umbellata* (Fischer), Figure 2E. Shell vestige of *?Grimpoteuthis meangensis* (Hoyle).

somewhat more detailed description is given. To it are added Figure 2 A-C which supplement the figure given by Verrill of the left second arm of his specimen, which is of somewhat dubious value.

The body is short, thick and fleshy, rounded posteriorly, and with large, fleshy fins, somewhat resembling those of *R. megaptera* Verrill. The fin insertion is about 2/3 of the mantle length. The anterior lobe of the fin is free while the fin itself projects slightly anteriorly of the mantle edge. The head is large, with prominent eyes, and is about ¾ as wide as the mantle. The integument is smooth.

The sessile arms are about ¾ of the mantle length, stout, in the order 3.2=4.1, the dorsal pair prominently keeled. The fourth pair of arms are stout and bordered laterally by a stout membrane which connects the third arms to form a deep pocket for the reception of the tentacle stalks. The arms are united by a deep web which is about 40 per cent of the arm length, deepest in the sector between the third and fourth arms, and completely disappearing between the ventral arms which are deeply cleft. The arm suckers are as described by Verrill, small, with small apertures, arranged in two rows proximally but immediately being distinctly four rowed and crowded medially, less so distally.

The tentacular arms are rather stout, of moderate length, triangular, rounded on the aboral surface, but flat and slightly grooved orally. The club is only slightly expanded, round, and bordered dorsally by a broad swimming membrane or keel which has its origin slightly proximal to the club and extends to the tip. The suckers are small and are arranged in about 16 rows. They have very short, slender stalks.

The funnel is short, thick, with a rounded, subterminal flap. The funnel organ is an inverted V-shaped body, small, compact with a slender, broadly triangular papilla anteriorly. The ventral pads are narrowly oval (Figure 2C).

Measurements (in mm) of a gravid female of *Rossia brachyura*.

Mantle length	43.0	Arm length	
Mantle width	30.0	1st pair	29.0
Head width	30.0	2nd "	32.0
Fin insertion	26.0	3rd "	34.0
Fin length	36.0	4th "	32.0
Fin width	56.0		

In the gravid female the nidamental glands are large, conspicuous, and occupy the major part of the visceral cavity. A small U-shaped

accessory nidamental gland is also present. The eggs are about 3.0 x 4.0 mm.

In alcohol the color is pale with small reddish chromatophores dorsally and larger ones which are crowded and somewhat fused ventrally.

Rossia (Semirossia) sp.

Among the cephalopods taken by the ATLANTIS are 148 specimens from 37 stations located on both coasts of Cuba of sepiolids here tentatively identified as members of the subgenus *Semirossia.* They represent over half of the total cephalopods taken during the cruises and are one of the commonest benthic forms of the West Indies. With few exceptions the specimens are females, and as none of the males can be definitely linked to the females, the specific identity must remain in doubt.

The males, although distinctly belonging to the *Semirossia,* cannot at this stage of our knowledge of the group be assigned to any of the known species. With the material at hand and the problematical status of the females it was felt that they should not be described as a new species until such time as the entire genus can be revised.

Detailed studies of the hectocotylized arm, the tentacular suckers, and the spermatophores were undertaken without success. Evidently there are two types of spermatophores involved in the group at hand, part of them approaching the structure of *Semirossia tenera,* the others deviating in certain respects. The external morphology is nearly identical.

If the females belong to the same species as the males then there is a strong difference in size between the sexes, a fact not hitherto recorded.

The whole problem of the genus *Rossia* is a perplexing one and cannot be solved until all of the species have been critically examined upon a sounder basis than has formerly been used. Some species have been thrown into synonymy without adequate comparison and others have been created upon minor details which, it is felt, will not stand up under critical observation.

It is possible, due to their size and locality, that the females might belong to *Rossia equalis* Voss (1950), but as no males referrable to this species were found in the collections this must also remain in doubt.

Genus *Heteroteuthis* Gray

Subgenus *Stephanoteuthis* Berry, 1909, emended

Body sepiolid-like, somewhat pointed posteriorly; mantle margin

free, ventral mantle margin produced forward covering or nearly covering the funnel; fins large, semicircular, placed somewhat posteriorly; head large, broad; arms short, stout, the suckers arranged biserially; the distal portion of the second pair of arms and some of the others devoid of suckers; tentacles stout, club not expanded, covered with minute suckers.

Remarks. The genus *Stephanoteuthis,* formerly considered synonymous with *Heteroteuthis* Gray, 1849, is here emended for the reception of those species which have at least some of their arms devoid of suckers on their extremities. At the present state of our knowledge of this group it appears to be distinct from *Heteroteuthis* s. s. in having a somewhat more elongate body, part of the extremities of some of the arms devoid of suckers, and the smooth bladelike conformity of the second pair of arms. The subgenus *Stephanoteuthis* contains the species *hawaiiensis, hawaiiensis dagamensis,* and *atlantis* n. sp.

Heteroteuthis (*Stephanoteuthis*) *atlantis* n. sp.
(Figures 3A-F)

Holotype. Female, in alcohol, from Sta. 3367, off Puerto Tanamo in 640 fms., April 19, 1939. MCZ Cat. No. 155019.

Description. This beautiful little squid is very compactly built. The body is stout, roundly pointed posteriorly, slightly projecting on the dorsal margin, and about ½ as wide as long. Ventrally the mantle extends sharply forward of the dorsal margin, emarginated on the anterior edge, and nearly covers the tip of the funnel.

The fins are large, semicircular, about 60 per cent of the mantle length, and inserted obliquely with free anterior and posterior lobes. The posterior edges of the fins do not reach the end of the mantle. (Figures 3A, B).

The head is large with prominent eyes which project beyond the mantle width. The sessile arms are in the order 2.1.3.4. The second pair of arms is the longest (Figure 3E). The arms of this pair are broadened, somewhat flattened, and have the distal 60 per cent of the arms devoid of suckers. The suckerless portion is smooth, slightly recurving and blade-like. The remaining arms have the suckers in two rows: those of the ventral and dorsal pairs rather small, the suckers of the third pair rather large. The suckers of all of the arms become minute distally, the tips of the dorsal pair of arms devoid of suckers and ridged on the oral surface. There are no keels on the dorsal arms.

The tentacles (Figure 3D) are stout, flattened on their oral surface and slightly grooved. The clubs are conspicuously smaller than the

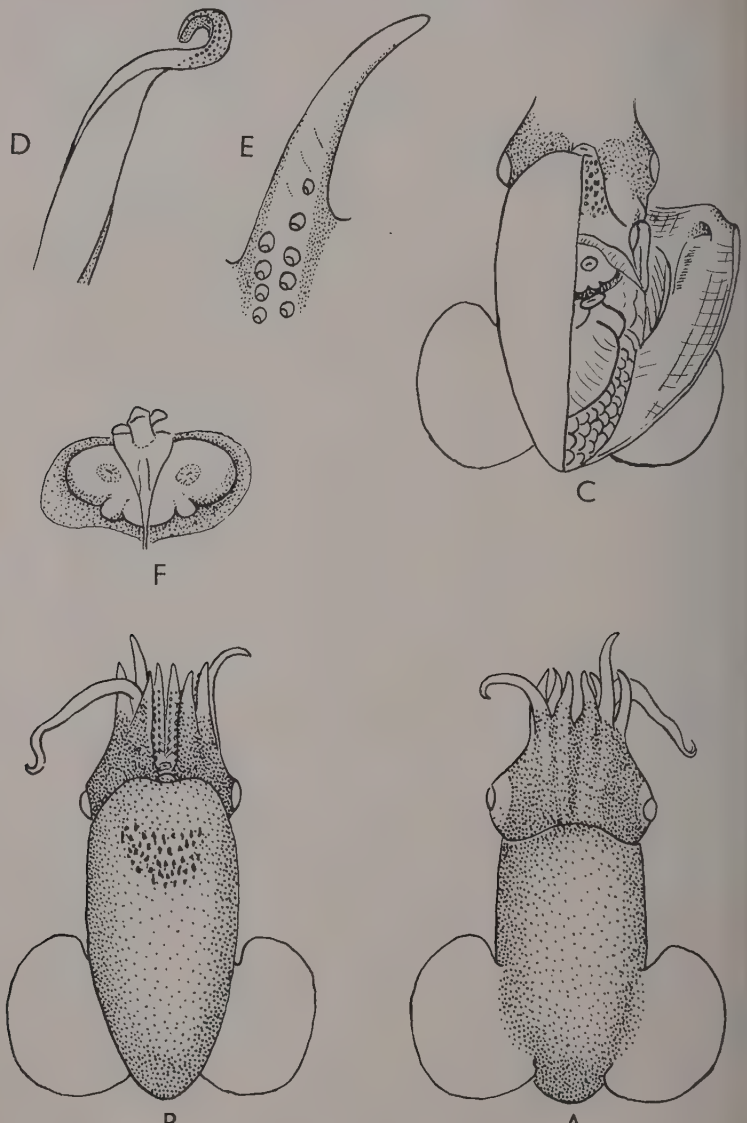

FIGURE 3. *Heteroteuthis atlantis* n. sp. A. Dorsal view, B. Ventral view, C. Ventral view, mantle cavity open, D. Left tentacle, E. Left dorso-lateral arm, F. Photogenic organ on ventral surface of ink sac.

stalks, round, and covered with minute pedunculate suckers crowded into numerous rows.

The funnel is short, stout, free for the distal 1/3 and covered with purple chromatophores over its entire length. The funnel organ is not distinguishable.

Internally a large, broad, five-lobed photogenic organ (Figure 3F) almost completely covers the ventral surface of the free ink sac. The lateral lobes each have a prominent pore situated in the middle of the lobe, appearing as a mammilar projection with a large central pit. A large nidamental gland (Figure 3C) occupies the majority of the mantle cavity and posteriorly covers the rather large eggs which have a diameter of 1.3 x 2.0 mm in diameter.

Measurements (in mm) of the holotype of *Heteroteuthis atlantis* n. sp.

Mantle length, dorsal	27.0	Arm length	
Mantle length, ventral	31.0	1st pair	9.1
Mantle width	15.0	2nd "	12.0
Head width	17.0	3rd "	9.0
Fin insertion	10.0	4th "	9.0
Fin length	16.0		
Fin width	31.0		

The color in alcohol was a deep purplish red dorsally, with smaller, more scattered chromatophores on the ventral surface. These become larger and more crowded in an oval area on the ventral surface near the anterior edge. The fins and the distal ¾ of all of the arms are devoid of color.

Remarks. The present species is distinct from all of the other known species; *H. dispar, H. sirventyi, H. weberi,* and *H. hawaiiensis,* by (1) the distal ends of the first and second pairs of arms alone being devoid of suckers, (2) the curious enlargement and flattening of the second pair of arms into blade-like structures, (3) the arm formula 2.1=3=4, and (4) the five-lobed photogenic organ of the ink sac. It has a close affinity with *H. hawaiiensis* Berry but as is seen from the description, it is quite distinct from this species. Unfortunately a detailed examination of the last named species is impossible at this date. The type, USNM Cat. No. 214311, is no longer extant, and no other specimens are available. Hence any comparison between the species is impossible for the purpose of more clearly defining the subgenus. It is entirely possible that such an examination may reveal the advisability of raising it to generic rank.

Robson's (1924) description of *H. hawaiiensis* var. *dagamensis* shows that his subspecies is not similar to the present species. In his

specimen all but the second arms have a keel, a character lacking in the present species. Although I am not certain that Robson's species does not represent a distinct species, it cannot be shown at the present time as certain features, such as the photogenic organ, are undescribed.[1]

Nectoteuthis pourtalesi Verrill, 1883

Nectoteuthis pourtalesi Verrill, 1883, p. 108.

Material. 1 male, ML 9.8 mm, Sta. 3466, 200 fms. off Matanzas, 14 foot Blake trawl, May 9, 1939. MCZ Cat. No. 154503.

1 male, ML 9.8 mm, Sta. 3427, 240 fms. off Caibarien, 35 foot otter trawl, May 1, 1939. MCZ Cat. No. 155012.

1 gravid female, ML 9.2 mm, Sta. 3467, 215 fms. off Bahia de Matanzas, 14 foot Blake trawl, May 9, 1939. MCZ Cat. No. 155016.

1 juv., ML 5.5 mm, Sta. 3396, 180 fms. off Cayo Coco, 35 foot otter trawl, April 28, 1939. MCZ Cat. No. 155018.

1 female, ML 8.0 mm, Sta. 3401, 230 fms. off Cayo Coco, 35 foot otter trawl, April 28, 1939.

This small and beautiful species of myopsid squid has been well described and illustrated by Verrill (1883) from the BLAKE cruises and little can be added here. A minute examination of the males and females disclosed no apparent trace of hectocotylization. The spermatophores of the specimens from Sta. 3466 were examined, but the details of the structure were obscure. The spermatophores are very large; in the specimen of 9.8 mm the spermatophore was about 9.0 mm in length and rather stout.

Verrill's single specimen was captured from 180 fms. off Barbados The conjecture that the curious pedicels of the suckers and the union of the dorsal arms by a web are male characteristics is disproved and they are instead shared by both sexes.

Family LOLIGINIDAE d'Orbigny

Lolliguncula brevis (Blainville, 1823)

Loligo brevis Blainville, 1823. p. 133.

Loligo brevipinna Lesueur, 1824. p. 282.

Loligo hemiptera Howell, 1868. p. 239.

Material. 2 juv., Sta. 3421, 235 fms. off Cayo Frances, April 30, 1939.

2 juv., Sta. 3418, 195 fms. off Cayo Frances, April 30, 1939.

[1]Since this paper was written another specimen of *H. atlantis* has come to hand. This specimen was taken from the Mediterranean in the Straits of Messina. It corresponds exactly to the description of the holotype in all characters described for the species. Thus the distribution of this species well overlaps that of the well known *H. dispar.*

1 juv., Sta. 3428, 240 fms. off Cayo Fragoso, May 1, 1939.
8 juv., Sta. 3416, 200 fms. off Cayo Frances, April 30, 1939.
5 juv., Sta. 3417, 200 fms. off Cayo Frances, April 30, 1939.
8 juv., Sta. 3423, 245 fms. off Cayo Fragoso, April 30, 1939.
8 juv., Sta. 3422, 235 fms. off Cayo Fragoso, April 30, 1939.
1 juv., Sta. 3414 fms. off Cayo Frances, April 29, 1939.

It is interesting to note that of the 35 specimens contained in the collections, none of them were adult or even half grown. This species is more or less confined to coastal areas, bays and lagoons of average salinity and it is seldom recorded in the literature from offshore waters.

The presence of these young specimens from depths of from 195 to 235 fathoms is difficult to explain as the adults are surface or shallow water dwellers. It can only be conjectured that the adults retire to deep water to spawn and that the young continue to dwell in moderate depths until nearing maturity when they seek the shallow coastal waters. As can be seen by referring to the station lists, all of the specimens were collected within a rather small area and in a short interval of time. This is one of the commonest Western Atlantic species and ranges from Rio de Janeiro, Brazil to Chesapeake Bay and Bermuda.

Sepioteuthis sepioidea (Blainville, 1823)

Loligo sepioidea Blainville, 1823, p. 133.
Sepioteuthis biangulata Rang, 1837, p.73.
" *sepioidea,* d'Orbigny, 1839, p. 34.
" *sloani* Leach, 1849, p. 81.
" *ovata* Gabb, 1868, p. 193.
" *ehrhardti* Pfeffer, 1884, p. 63.
" *occidentalis* Robson, 1926, p. 352.

Material. 1 female,1 male, in alcohol, taken with a dip net and light at surface, Bahia Cochina, February 23, 1938.

These are both adults of large size and are the only specimens of this species taken by the expedition. It is a coastal species ranging from the West Indies northward to Cape Canaveral on the Florida coast and the Bermudas, but it is absent from the Gulf of Mexico. This species is found most abundantly in inshore waters, and is a rather agile and rapid swimmer.

Both of the specimens were dissected and the stomach contents examined. They were found to have been feeding on a polychaete worm, *Nereis glandulata* Hoagland, which apparently was swarming at the time.

Doryteuthis plei (Blainville, 1823)

Loligo plei Blainville, 1823, p. 132.

Doryteuthis plei, Naef, 1912, p. 742.

Material. 11 juveniles taken at night on the surface with a dipnet at Bahia Cochina, April 3, 1939.

These are rather small specimens, the largest with a mantle length of 35.0 mm, and no attempt was made to determine their sex. This species was first described from the West Indies by Blainville in 1823. It was later listed by d'Orbigny (1835), but was not reported again in the literature until Adam (1937) redescribed it. Apparently this is the species which has been listed from the Gulf of Mexico by Verrill (1882) and others as *Loligo gahi,* which is a Pacific coast species from Chile and Peru. It is commonly known as the arrow squid and is very common in the area around Key West and Dry Tortugas. It is known from as far north as Sea Island, Georgia but its southern range is unknown. It is an extremely active and swift swimmer, but is taken in fair quantities in shrimp hauls in Florida waters.

Division OEGOPSIDA

Family ENOPLOTEUTHIDAE Pfeffer

Abralia veranyi (Rüppell, 1844)

Enoploteuthis veranyi Rüppell, 1844, p. 3.

Abralia veranyi, Hoyle, 1886, p. 38.

Material. 1 male, Sta. 3432, 250 fms. off Cayo Fragoso, May 1, 1939.

1 male, Sta. 2980, 250 fms. off Cayo Frances, Blake trawl, March 16, 1938.

2 females, gravid, at night on the surface in Corrientes Bay Anchorage, March 26, 1939.

The only previous record of this species from the Western Atlantic is by Adam (1941) from Cockburn Town, San Salvador. Naef (1923) has given an excellent description of this species from the Mediterranean, including synonymy, anatomy, and development. Adam (1952) has beautifully illustrated this species from the west coast of Africa. Pfeffer (1912) and others have used the absence of light organs in a narrow strip down the median-ventral surface of the mantle as a specific character, but of the four specimens collected by the ATLANTIS two only show signs of this stripe, one very distinctly, while the others have no indication whatever. It would seem that such a character would be affected by contraction of the skin due to preservation, but Naef (1923) suggests that it may be an individual variation.

In the four specimens at hand all have 4 hooks on the hand part of the tentacular club; the proximal minute, the second the largest, and then gradually decreasing distally. The light organs on the eyeball are 5 in number, the two end ones much larger, the posterior sometimes with a slight sinus in the dorsal edge. The three intermediate light organs are small and nearly equal in size.

Abralia redfieldi n. sp.
(Figures 4A-H)

Holotype. Gravid female, University of Miami Marine Laboratory Sta. SL23 B, at surface off Gun Cay, Bahamas, December 10, 1953. MCZ Cat. No. 203979.

Paratype. Gravid female, Sta. 3436, 255 fathoms off Caibarien, May 2, 1939. MCZ Cat. No. 203980.

Description. Among the *Abralia* collected by the ATLANTIS was a single female with a mantle length of 28.0 mm. Upon examination this specimen, which is in rather poor condition, proved to represent a second and hitherto unknown species of *Abralia* from the Atlantic Ocean. The specimen is extremely flaccid, the tentacular hooks are missing and the specimen is in generally poor condition. Fortunately, while this paper was in the process of being written, another specimen, a female of 29.0 mm mantle length, was obtained by the Marine Laboratory of the University of Miami from a haul off Gun Cay in the Bahamas. This specimen was in perfect condition and was therefore chosen as the holotype of the new species. The following description is based primarily upon this specimen but supplemented by the original specimen when necessary.

This is a small species of squid, compact, and rather stout with a mantle width of 41.5-46.5 per cent of the mantle length (Figures 4A, B). The anterior mantle margin is slightly produced in the median-dorsal line. Ventrally the anterior margin is emarginated beneath the funnel with small sharp projections on either side. Posteriorly the body is bluntly pointed but the union of the two fins at the posterior end gives it the appearance of a long, somewhat pointed extremity. The fins are large occupying 47.2-55.2 per cent of the mantle length and very wide, 93.0-89.4 per cent of the mantle length, typically *Abralia*-like in contour.

The head is large, broad, 39.6-39.3 per cent of the mantle length, with prominent eyes. The arms are long, 51.8-60.5 per cent of the mantle length, stout, tapering to slender tips. The bases of the arms

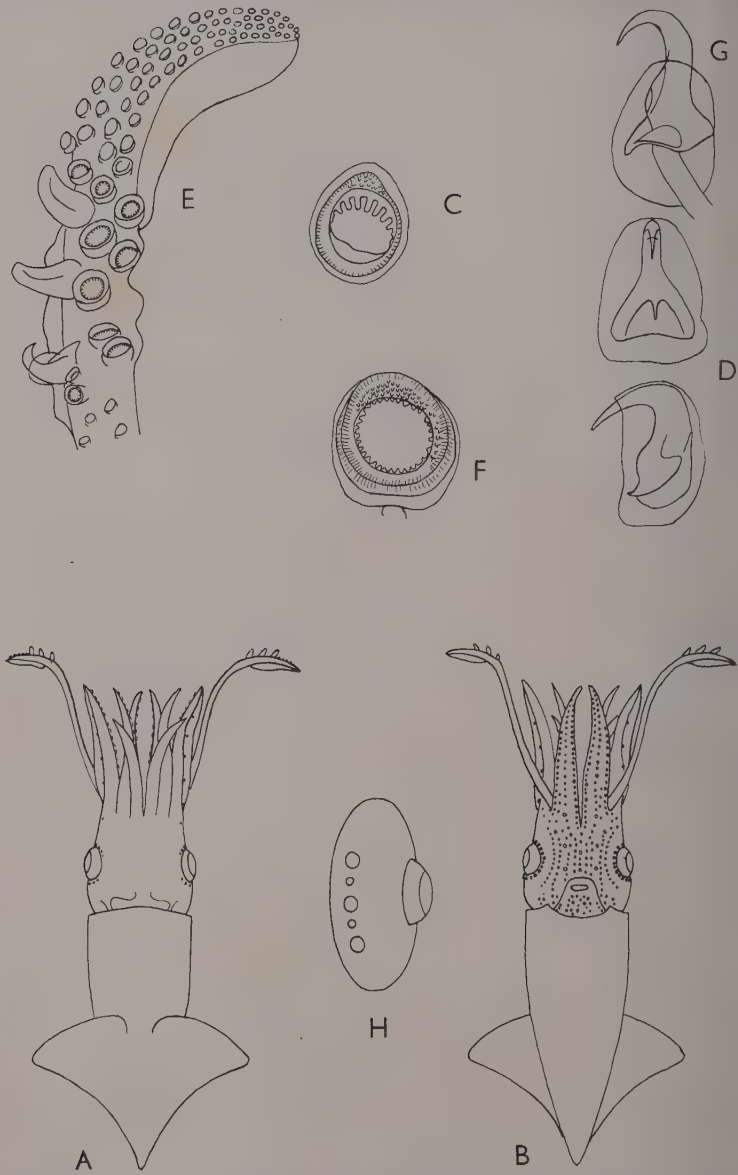

FIGURE 4. *Abralia redfieldi* n. sp. A. Dorsal view, B. Ventral view, C. Sucker of distal portion of left disto-lateral arm, D. Lateral and facing view of hook from left disto-lateral arm, E. Left tentacular club, F. Large marginal sucker from left tentacular club, G. Lateral view of tentacular hook, H. Eye, showing position of light organs.

are devoid of suckers or hooks, but soon become equipped with two rows of hooks which at the distal ends are replaced by suckers in two rows, whose horny rims bear about eight small square-tipped teeth in the distal margin (Figure 4C). The hooks (Figure 4D) are as follows on the arms: dorsal arms with 8 pairs of hooks, 2nd arms with 7 pairs of hooks, 3rd arms with 7 pairs of hooks, and ventral arms with 5 pairs of hooks. The third pair of arms are bordered by a broad swimming membrane.

Measurements (in mm) of two specimens of *Abralia redfieldi* n. sp.

	Holotype	Paratype
Mantle length	29.0	28.0
Mantle width	12.0	13.0
Head width	11.5	11.0
Fin width	27.0	25.0
Fin length	16.0	13.5
Arm length		
1st pair	13.5	15.0
2nd "	15.0	17.2
3rd "	15.0	17.1
4th "	14.0	17.2

The tentacles are of medium length, stout, with slightly expanded clubs equipped with both suckers and hooks (Figure 4E). The distal half of the club is bordered dorsally by a swimming membrane. The suckers and hooks are arranged in the following order: on the carpus is a cluster of 4 carpal cups and one or two pads; this is followed on the ventral margin by two small toothed suckers; there follows on the ventral margin three large hooks of nearly equal size, the middle one slightly larger than the other two (Figure 4G); the hooks are accompanied by three pairs of suckers (Figure 4F) on the dorsal side of the club; beyond these hooks and suckers are 4 rows of small toothed suckers which extend to the extremity of the club.

As in all the species of this genus the body, arms, head and eyes are liberally covered with light organs. As the distribution of these are of great taxonomic importance in this genus, the following account is given.

The mantle is sparsely supplied with light organs upon the sides and dorsal surface but ventrally they are crowded together so as to nearly cover the entire surface. In both the paratype and the holotype there is a clear strip down the median ventral line which is devoid of light organs. The light organs on the rest of the ventral surface are of two kinds: few but large somewhat clear organs with a darker periphery, and small and very numerous solid dark purple light

organs. Both of these types extend over the ventral surface of the funnel.

Dorsally the head and arms are devoid of light organs. There is a ring of about 28 to 30 photophores around each eye, sparse dorsally and thickly crowded ventrally. The ventral surface of the head is covered with photophores of both types arranged in about 9-10 rows (Figure 4B). Of these, three rows extend onto the ventral surface of each of the ventral arms. The 3rd pair of arms has a single row of large, widely spaced light organs at the base of the swimming membrane, extending from the base of the arm to the tip.

On the eyeball, arranged in a line around the periphery of the bulbus, are five light organs (Figure 4H). These are of two sizes: the 1st, 3rd and 5th are about twice as large as the 2nd and 4th. All of them are round and of a similar appearance.

Remarks. The genus *Abralia* is primarily Indo-Pacific with 8 described species from that area. The sole representative, hitherto, in the Atlantic was *A. veranyi* which is known from the Mediterranean, Madeira, the West Coast of Africa, and the West Indies. The present species undoubtedly is closely related to this species but it differs from it in: (1) the shorter, heavier body, (2) somewhat shorter fins, (3) presence of only two rows of minute suckers on the tips of the sessile arms as contrasted with 4 in *A. veranyi,* (4) only 3 nearly equal hooks on the tentacular club, and (5) the size and arrangement of the light organs on the eyeball.

As the present specimens represent a new species of squid I have named it *Abralia redfieldi* for Dr. Alfred C. Redfield of the Woods Hole Oceanographic Institution through whose kindness I have been able to examine the present collections.

Pyroteuthis margaritifera aurantiaca Joubin, 1924.

Pyroteuthis margaritifera aurantiaca Joubin, 1924, p. 52.

Material. 1 gravid female, Sta. 2969, 1075-1145 fms. SE of Guantanamo Bay, Blake trawl, March 5, 1938, MCZ Cat. No. 203981.

A single specimen with a mantle length of 35 mm was taken at the above station. It is striking by the numerous and large reddish brown chromatophores crowded on the dorsal surface and the large scattered chromatophores on the bases of the fins. Ventrally the chromatophores are small, rather closely set, and not as noticeable as those on the dorsal surface.

The light organs are conspicuous within the mantle cavity and on the eyeball, but due to the fusion of the skin with the latter organ a

definite count of the light organs was not obtainable. Joubin reported this species from the Azores, an area which shows a strong affinity with the Gulf of Mexico and the Caribbean in its fauna.

Family ONYCHOTEUTHIDAE Gray

Onychoteuthis banksi (Leach, 1817)

Loligo banksii Leach, 1817, p. 141.

Material. 1 male in alcohol, Sta. 3015, surface at night with light between Cat Cay and Miami, Florida, March 27, 1938. MCZ Cat. No. 203982.

A single specimen of this well known circumtropical squid was taken from the above station. This is an active and fast swimming species and is not generally taken in net hauls. Although commonly limited to warm waters it has been taken from as far north as Hammerfest, Norway and as far south as Cape Horn. The present specimen is a young male with a mantle length of 78.0 mm.

Family OMMASTREPHIDAE Gill

Illex illecebrosus (Lesueur, 1821)

Loligo illecebrosus Lesueur, 1821, p. 95

Ommastrephes illecebrosus, Verrill, 1872, p. 281

Illex illecebrosus, Steenstrup, 1880, p. 90?

Material. 1 female, Sta. 3432, 250 fms. off Caibarien, May 1, 1939.

2 females, Sta. 2984, 240-250 fms. off Caibarien, March 12, 1938.

1 female, Sta. 2981c, 195 fms. off Punta Alegre, March 10, 1938.

1 female, Sta. 3411, 260 fms. off Punta Alegre, April 29, 1939.

2 females, Sta. 3422, 235 fms. between Punta Alegre and Caibarien, April 30, 1939.

1 female, Sta. 2963, 190-180 fms. off Bahia de Cochinos, February 25, 1938.

1 female, Sta. 3421, 235 fms. between Punta Alegre and Caibarien, April 30, 1939.

1 female, Sta. 2999, 145-230 fms, off Matanzas, March 17, 1938.

2 females, Sta. 3423, 245 fms. off Caibarien, April 30, 1939.

1 female, Sta. 3387, 245 fms. off Cayo Romano, April 26, 1939.

1 male, Sta. 3414, 230 fms. between Punta Alegre and Caibarien, April 29, 1939.

This species is well represented in the collections by 14 specimens from 11 stations. This is a common squid of the Gulf of Mexico and Caribbean region. On the European side of the Atlantic it is represented by the subspecies *I. illecebrosus coindetti,* from which it differs

in many respects (see Pfeffer, 1912, Adam, 1952). *I. illecebrosus illecebrosus* is found across the upper North Atlantic to the European coast. New England to Cape Hatteras, the Gulf of Mexico and Cuba.

Family CRANCHIIDAE Gray

Liocranchia reinhardti (Steenstrup, 1856)

Leachia reinhardti Steenstrup, 1856, p. 200.

Material. 1 specimen, in alcohol, Sta. 2999A, 145-230 fms. off Matanzas, March 17, 1938. MCZ Cat. No. 203983.

A single specimen with a mantle length of 66.0 mm is represented in the collections. This is probably an adult, although full grown specimens from Japanese and Philippine waters attain a much greater size. It is easily recognized by the dorsal row of tubercles in the mid-line and the inverted V-shaped row of tubercles on either side of the funnel at the point of fusion with the mantle.

This is apparently the first record of this species from the Western Atlantic. It is planktonic in habitat and cosmopolitan in distribution.

Cranchia scabra Leach, 1817.

Cranchia scabra Leach, 1817, p. 410.

Material. 1 specimen, in alcohol, Sta. 2972A, 1200 fms. Windward Passage off Oriente, May 6-7, 1938. MCZ Cat. No. 135081.

This specimen with a mantle length of 23.0 mm belongs to one of the common species of the Cranchiidae and is easily recognized by the subglobular form and heavily tuberculated skin. It attains a length of about two to three inches in mature individuals. This is the first record of this species from the Western Atlantic although the author has taken immature forms in the plankton hauls off Miami, Florida. In common with the other members of the family it is planktonic in habitat.

Verrilliteuthis hyperborea (Steenstrup, 1856)

Leachia hyperborea Steenstrup, 1856, p. 200

Desmoteuthis tenera Verrill, 1882, p. 412

Taonius hyperboreus, Hoyle, 1886, p. 191

Desmoteuthis hyperborea, Pfeffer, 1912, p. 708

Verrilliteuthis hyperborea, Berry, 1912, p. 643

Material. 1 specimen, in alcohol, Sta. 2959, 2050 fms. south of the Isle of Pines, 2 meter net, February 15-16, 1938. MCZ Cat. No. 203984.

1 specimen, in alcohol, Sta. 2999A, 145-230 fms. off Bahia de Matanzas, March 17, 1938. MCZ Cat. No. 203985.

Two specimens, which I have referred to this species, were obtained in very poor condition. This species is confused in the literature under several different names and has been recorded by Johnson (1934) under the name *Taonius tenera* Verrill and under its present name from Greenland to Massachussetts. It seems to be rather widely distributed in the North Atlantic, and is strictly planktonic.

Suborder *OCTOPODA*

Family STAUROTEUTHIDAE Robson

Grimpoteuthis umbellata (Fischer, 1883)

(Figure 2D)

Cirroteuthis umbellata Fischer, 1883, p. 404.

Material. 1 gravid female, Sta. 2967B, 1330-1650 fms. off Guantanamo, 14 foot Blake trawl, March 4, 1938. MCZ Cat. No. 203986.

This specimen is in fair condition, but the outer integument is missing and much of the web. It is tentatively placed in this species, but it presents some characters which cannot be settled without comparison with other specimens. The total length is about 250.0 mm with a dorsal mantle length of 46.0 mm. The mantle width is about 72.0 per cent of the mantle length, while the interocular width equals the mantle length. The eyes are large and prominent, about 38.0 per cent of the mantle length. The arms are 74.0 per cent of the total length and in the order 1.2.3.4. The suckers are 4.0 per cent of the mantle length, uniserial, and bordered on either side by cirri which are about 2½ times the diameter of the suckers, and extend to the distal extremity of the arms. The web is so damaged that no observations are possible.

The fins are long and slender, the length of the individual fin being 47.0 mm while the breadth across both fins is 129.0 mm. They are slender, rounded at the extremities, the width about 1/4 the length of the fin. The dorsal cartilage is horse shoe-shaped, the ends lying parallel, the posterior curve forming part of the arc of a circle (Figure 2D). The funnel is slender, compact, and projects through a narrow mantle opening.

The present specimen is a gravid female and contained 6 large eggs about 12.5 X 7.0 mm. The surface is sculptured by a series of rough irregular longitudinal ridges. Of the six large eggs one was lodged in the oviduct just below the large oviducal gland. A dozen small eggs about 1/4 the size of the others were situated on the dorsal surface of the ovary.

As can be seen this specimen shows a close affinity with *G. umbel-*

lata and also with *G. megaptera* (Verrill) due to the size of the fins. It differs from the latter, however, in the much larger eyes which seem to exclude it from that species. Joubin has described a specimen of *G. umbellata* from the Sigsbee Deep which, however, is not adequate for comparison with the present specimen. This species seems to be well distributed in the Eastern Atlantic although this is only the second record from the Western Atlantic.

?*Grimpoteuthis meangensis* (Hoyle, 1885)
(Figure 2C)

Cirroteuthis meangensis Hoyle, 1885, p. 234.
Material. 2 specimens, Sta. 3305, 330 fms. off Playa Baracoa, 14 foot Blake trawl, March 23, 1939. MCZ Cat. No. 203987.

The two specimens recorded above are doubtfully placed in this species on the basis of the record of this species from the Mediterranean by Lo Bianco and the illustrated shell vestige by Robson (1931). The arms and web are the sole remains and these are in such a bad state of preservation that little can be told from them. The suckers are small and bordered by small, conical short cirri which are continued to the arm extremities or nearly so. The shell vestige is shown in Figure 2C. It is unfortunate that both specimens are nearly completely destroyed and no detailed description can be given.

Family Opisthoteuthidae Verrill
Opisthoteuthis agassizi Verrill, 1883.

Opisthoteuthis agassizi Verrill, 1883, p. 113.
Material. 1 specimen, Sta. 3370, 450 fms. off Puerto Tanamo, April 20, 1939. MCZ Cat. No. 203988.

The single specimen referred to this species was in a dried condition and returned to alcohol. Although most of the body characteristics have been destroyed the mantle length appears to be about 12.0 mm. The oral face of the web and arms is in fair condition and from the position and arrangement of the suckers it is placed without hesitation in the above species. It is known previously from the West Indies (Verrill) and off the southwestern coast of Ireland (Chun, from MICHAEL SARS material).

Family Bolitaenidae Chun
Eledonella pygmaea Verrill, 1884

Eledonella pygmaea Verrill, 1884, p. 145
Japetella prismatica Hoyle, 1885, p. 231
Eledonella massyae Robson, 1924, p. 202

Eledonella ijimai Sasaki, 1929, p. 13
Eledonella massyae purpurea Robson, 1930, p. 379
Material. 1 female, Sta. 2972A, 3510 m. off Baracoa, March 7, 1938. MCZ Cat. No. 203989.

This delicate, gelatinuous, bathypelagic species has recently been monographed by Sven Thore (1949) and little can be added here of value.

The present specimen is small and is in very poor condition so that a critical examination is not possible. Two other specimens, definitely assignable to this species, were captured in the central Bahamas on the voyage down. They agree in all ways with Thore's data. They have a nearly worldwide distribution, being found in all seas but the Arctic, in very deep water.

Family Octopodidae d'Orbigny

Genus *Tetracheledone* n. gen.

With the characters of the species.

Type species: *Tetracheledone spinicirrus* n. sp.

Tetracheledone spinicirrus n. sp.
(Figures 5A-H)

Holotype. Male, in alcohol, Sta. 2999A, 145-190 fms. off Matanzas, 10 foot Blake trawl, March 17, 1938. MCZ Cat. No. 203990.
Paratypes. Female, in alcohol, Sta. 3439, 295 fms. off Caibarien, 60 foot otter trawl, May 2, 1939. MCZ Cat. No. 203991.

Male, in alcohol, M/V Antillas, 105 fms. ESE of Jacksonville Beach, Florida, May 1, 1952. To be deposited in the U. S. National Museum.

Male, in alcohol, Sta. 2999A, 145-190 fms. off Matanzas, 10 foot Blake trawl, March 17, 1938. Museo Poey, Havana, Cuba.
Additional material. Fragmented female, Sta. 3432, 250 fms. off Bahia de Cochinos, 35 foot otter trawl, May 1, 1939.

Male, partly torn, M/V OREGON, Sta. 489, Gulf of Mexico.

This new and interesting tropical eledonid is a small species from moderate depths (Figure 5A). The body is globular and nearly as wide as the mantle length. The head is 63.0 to 75.0 per cent of the mantle length with rather small eyes. The arms are nearly subequal, in the order 3=2.1.4 in the holotype, and 59.0 to 66.0 per cent of the total length with a rather deep web which is 43.0 to 45.0 per cent of the arm length in the adult, the sectors C or B being the deepest but the others subequal. The suckers are uniserial, small and deeply

set with an index of 5.3 to 9.0 per cent of the mantle length. The surface of the mantle, head, web and arms is closely set with large, stellate papillae which give this species a characteristically spinous appearance. In the small female a skinfold surrounds the mantle, similar in appearance to that of *Scaeurgus unicirrhus*. In the holotype this fold consists only of a raised line of stellate tubercles running around the mantle from the corner of the funnel opening. Additional specimens show this ridge distinctly. Over each eye there are two large cirri which are armed with spinous protuberances arranged in circles about the cirrus. In some specimens these cirri are retracted into pit-like depressions at their bases.

Measurements (in mm) of 3 specimens of *Tetracheledone spinicirrus* n. sp.

	Holotype		Paratype		Paratype	
Sex	Male		Female		Male	
Mantle length	37.0		15.0		42.0	
Mantle width	30.0		14.0		41.5	
Head width	25.5		10.5		26.5	
Sucker diameter	2.2		.8		3.8	
Arm width	4.8		1.8		4.5	
Length hect. arm	46.0		——		62.0	
Ligula length	2.0		——		4.5	
Calamus length	0.5		——		1.5	
Length penis and diverticulum	4.0		——		7.0	
Arm length	R	L	R	L	R	L
1st pair	53.0	51.0	20.5	23.0	77.0	72.0
2nd "	54.0	54.0	22.0	20.0	81.0	79.0
3rd "	46.0	54.0	20.0	25.0	62.0	71.0
4th "	51.5	52.0	——	21.5	64.0	71.0
Web depth						
Sector A	17.5		7.0		27.0	
" B	22.5		7.0		35.0	
" C	23.5		7.0		33.0	
" D	20.0		6.2		29.0	
" E	19.5		——		25.0	

The funnel is short and stout. The funnel organ is very distinctive (Figure 5B), consisting of four small stoutly oval, widely separated pads showing not the slightest trace of union with one another. They seem to correspond to the pads found in the genus *Teretoctopus*, but are not similar to those found in *Thaumeledone brevis* which are thin strips.

The internal anatomy was partially dissected out of the OREGON specimen. The radula consists of a simple, unicuspid rhachidian, small admedians, second laterals with a single stout tooth, saber like third

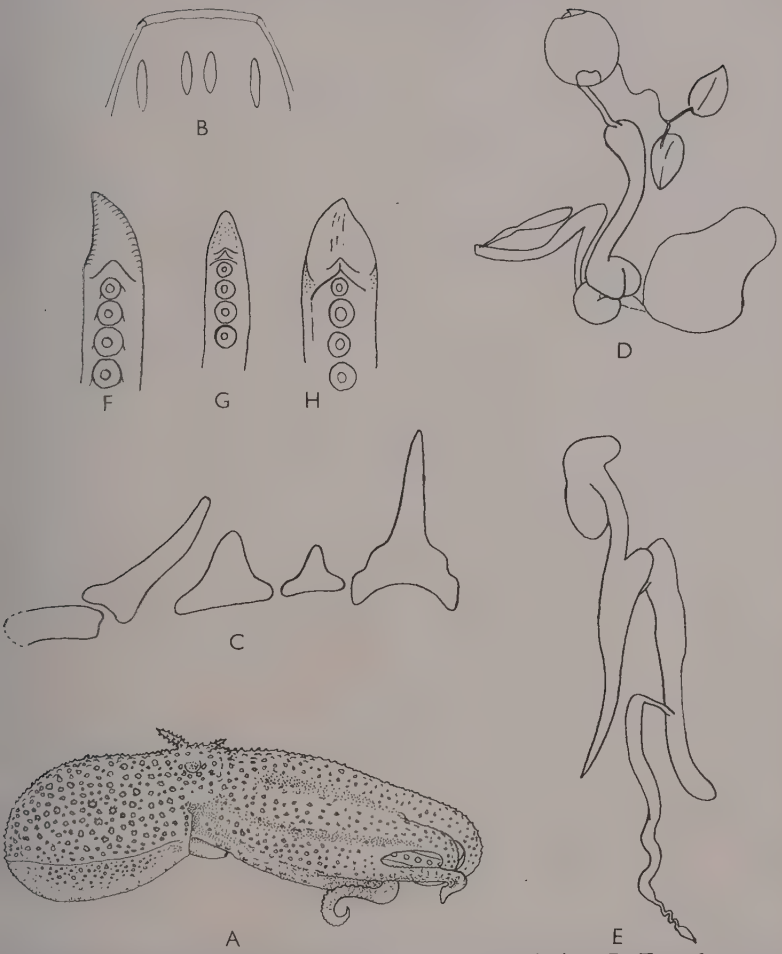

FIGURE 5. *Tetracheledone spinicirrus* n. sp. A. Lateral view, B. Funnel organ, C. Radula, D. Digestive tract, E. Male genitalia, F. Ligula of Gulf of Mexico specimen, G. Ligula of holotype, H. Ligula of paratype from Jacksonville, Florida.

laterals and flat, plate-like marginals (Figure 5C). The gills are rather large, with 7 to 9 filaments per demibranch and are 22.0 to 32.0 per cent of the mantle length. The inner and outer demibranchs seem similar.

The alimentary tract consists of closely adhering anterior salivary glands bright orange in color, rather large posterior glands attached to the buccal mass by long ducts, a stout esophagus and rather prominent crop. The stomach is externally divided into two parts, a heavy muscular proximal section and a thin walled distal section. There is a stout spiral caecum and large liver. There is a tendency towards a second stomach. An ink sac is present which is not involved in the liver except superficially.

The male genital organs were dissected out and are figured in Figure 5E. The penis is short and thick, and has a large diverticulum. There were no spermatophores present in any of the specimens. Externally the hectocotylized arm bears a small, spade-like ligula which is 4.3 to 7.2 per cent of the hectocotylized arm (Figures 5F-H). There are no transverse ridges apparent. The calamus is about 25.0 to 33.4 per cent of the ligula, consisting of a simple fold which is continuous with the spermatophoral groove.

Remarks. While I naturally hesitate to form a new genus to contain this single species there is none known in which it can properly be placed. The uniserial suckers, stellate warts, well developed ink sac, and peculiar four pads of the funnel organ preclude placing this species in any of the other eledonid genera. As known at present it is a tropical species occurring from north Florida on the Atlantic coast to both the north and south coasts of Cuba and the Gulf of Mexico.

In consideration of the above noted peculiarities I have given this species the generic name *Tetracheledone (tetracha,* in four parts, and *eledone,* a kind of octopus) in order to show its relationship to the eledonids and the peculiar four pads of the funnel organ, and the trivial name *spinicirrus* from the spiny appearance of the ocular cirri.

Octopus sp.

Material. 1 male, Sta. 2999A, 145-190 fms. off Matanzas, March 17, 1938.

A single male in rather poor condition was taken at the above station and for want of more material cannot be identified at this time. The body is saccular, somewhat soft and gelatinous, with a mantle length of 29.0 mm. The surface is mostly smooth, but bears a cluster of large papillae over each eye and about two cirri. The arms are long and there are indications of the presence of a deep web, especially between the dorsal arms. The third right arm is hectocotylized, and there is a very small ligula without a calamus. There are

about 7 filament on the outer demibranch of the gill. The penis is long and slender with a small coiled diverticulum. The large ink sac is deeply involved in the liver.

Although this specimen is unlike any known species from this area it does not seem wise, considering the state of the specimen and no other material at hand, to describe it at this time.

Scaeurgus unicirrhus (d'Orbigny, 1840)

Octopus unicirrhus Orbigny, 1840, p. 70
Scaeurgus unicirrhus, Tiberi, 1880, p. 12
Scaeurgus patagiatus Berry, 1913, p. 564
Material. 1 female, Sta. 2999, 145-230 fms. off Matanzas, March 17, 1938. MCZ Cat. No. 203992.

This small specimen with a dorsal mantle length of 19.0 mm is the only specimen taken by the cruises. It has been reported by Voss (1951) from the Florida coast and a single specimen was taken by the Cuban hydrographic vessel YARA in the middle of the Florida Straits between Havana and Key West. It is a benthic species from moderate depths and is distributed from the Mediterranean Sea to the Azores, tropical Western Atlantic, the Pacific and Indian Oceans. The skin fold around the sides of the mantle, the rough surface, and the male hectocotylus on the third left arm serve to identify this species.

Pteroctopus tetracirrhus (Delle Chiaje, 1830)

Octopus tetracirrhus Delle Chiaje, 1830, p. 72.
Scaeurgus titanotus Troschel, 1857, p. 51.
Scaeurgus tetracirrhus, Tiberi, 1880, p. 12.
Pteroctopus tetracirrhus, Fischer, 1882, p. 334.
Material. 1 female, Sta. 3435, 255 fms. off Caibarien, 60 foot otter trawl, May 2, 1939. MCZ Cat. No. 203993.

2 females, Sta. 3439, 295 fms. off Caibarien, 60 foot otter trawl, May 2, 1939.

1 female, Sta. 3431, 245 fms. off Caibarien, 35 foot otter trawl, May 1, 1939.

2 females, Sta. 2982C, 195-225 fms. off Punta Alegre, 35 foot otter trawl, March 11, 1938.

1 female, Sta. 2995, 370-605 fms. off Bahia de Cardenas, 35 foot otter trawl, March 16, 1938.

1 female, Sta. 2982, 210 fms. off Punta Alegre, 35 foot otter trawl, March 11, 1938.

This species has previously been recorded by Voss (1954) from

the Western Atlantic from specimens collected on the Florida coast. Previous to the Florida record it has been known from the Mediterranean, Cape Verde Islands, and recently from Africa by Adam (1952). It is easily recognized by the two large cirri over each eye and the hectocotylus of the male being on the third left arm as in *Scaeurgus*. The consistency is somewhat soft and gelatinous and the surface is covered with purplish red chromatophores.

Family Argonautidae Cantraine

Argonauta hians Solander, 1786.

Argonauta hians Solander, 1786, p. 44.

Material. 1 female, North Atlantic (information contained upon printed Harvard-Havana Exped. label) MCZ Cat. No. 203994.

The single specimen bearing the above label was taken by the ATLANTIS complete with shell. It is unfortunate that no other data are available as the label raises some doubts that the specimen came from Cuba. However, this species is widely distributed in the West Indies and there seems to be no valid reason for not including it in the present paper. The animal is badly distorted by the preservative so that measurements are unobtainable. The shell has a greatest diameter of 31.0 mm and a width of 25.0 mm across the ears.

Although this is a rather rare shell upon the beaches in the West Indies, the examination of a number of stomachs of the fish, *Coryphaena hippurus,* has revealed that they occur in considerable numbers in the open ocean. The species is world wide in distribution in tropical and subtropical waters.

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A CONTRIBUTION TO THE LIFE HISTORIES OF COMMERCIAL SHRIMPS (Penaeidae) IN NORTH CAROLINA[1]

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ABSTRACT

This paper reviews the estuarine portion of the life histories of *Penaeus setiferus, P. duorarum* and *P. aztecus* in North Carolina. After larval migrations from spawning places at sea, the young enter estuaries as benthonic post-larvae. *P. setiferus* is judged to grow 36 mm, *P. duorarum* 52 mm, and *P. aztecus* 46 mm per month in brackish nursery areas during the warmer months. Juveniles gradually move toward the sea as they approach mature sizes. *P. aztecus* recruitment is greatest in May. The earliest recruits reach commercial size by July. No juveniles and few adults overwinter in N.C. *P. duorarum* recruitment extends from June to October. The earliest recruits reach commercial size in autumn, but the remainder overwinter and attain commercial size in spring. Mature adults occur in the littoral zone prior to the recruitment period. *P. setiferus* recruitment occurs chiefly in June. The young attain commercial size by late summer. A sparse population of adults overwinters in the littoral zone. These are sexually mature in spring.

A number of ecological factors in the nursery areas are discussed. The role of interspecific competition for nursery areas is considered. *P. aztecus* and *P. duorarum* occupy these areas at different times. *P. setiferus* may compete with both of these species for nursery ground.

INTRODUCTION

The purpose of this paper is to outline the portions of the life histories of *Penaeus setiferus* (Linn.), *P. duorarum* Burkenroad and *P. aztecus* Ives which occur in estuaries extending from Onslow County to Hyde County, North Carolina (Fig. 1). Two factors make this region an especially favorable place for these life history studies. First. the North Carolina penaeid shrimp fishery is the most northern one on the Atlantic coast of the United States. Although penaeid shrimps range north of North Carolina, occasionally to the southern shore of Massachusetts in summer, this fishery is probably near the northern limits of the breeding ranges for the different species. (Penaeid shrimps are present in Chesapeake Bay but trawling in the Bay is prohibited.) If any special adaptations in the life histories of the species are imposed by the northern geographic limits of the breeding

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ranges, they could be expected to be apparent here. Second, because of an unusual coastal geography, North Carolina has the largest sounds on the southeast coast of the United States. These large shallow sounds with their numerous tributaries provide abundant nursery areas for young shrimps.

FIGURE 1. Twenty-one eastern counties of North Carolina with associated coastal features. Shaded area indicates approximate extent of commercial shrimping grounds. White letters in solid circles indicate localities along western shore of Pamlico Sound from which samples of juveniles were taken in 1953 (see also Tab. 1).

HISTORICAL

The past 30 years have been a period of great advancement in knowledge of penaeid life histories throughout the world. The life histories of penaeids which occur in waters adjacent to the southeastern and southern United States have attracted special interest since the early 1900's, but of the three species which compose the bulk of American Atlantic commercial catches (*Penaeus setiferus, P. duo-*

rarum and *P. aztecus*), *P. setiferus* has received the most attention. Information on life histories of *P. duorarum* and *P. aztecus* is in the form of scattered notes and observations, or is listed under the name of *P. brasiliensis* with which these forms were formerly confused.

For the purposes of the study at hand, mention of the recent literature is deemed sufficient. Spaulding (1908) and Viosca (1920, 1923) were among the first to study *Penaeus setiferus* life history in Louisiana. Weymouth *et al.* (1933) contributed to the life history of *P. setiferus* in the Gulf of Mexico and along the coast of the southeastern United States. Burkenroad (1934, 1939) made systematic contributions with notes on reproduction and life histories. Pearson (1939) contributed a detailed study on early stages in the life history of *P. setiferus* and other species. King (1948) published results of histologic work on the reproductive organs of *P. setiferus*. Further life history data were supplied in a summary by Anderson *et al.* (1949) and by Burkenroad (1949). Gunter (1950) reported additional life history data. Broad (1950, 1951a) gave information on adult shrimps in North Carolina, and Heegaard (1953) discussed larval stages of *P. setiferus*.

Various penaeid life histories, or portions of life histories, have been treated by Hudinaga (1942) in Japan, Dakin (1938, 1940, 1946) in Australia, Heldt (1938) in North Africa, Gurney (1944) in Bermuda, Menon (1952) along the southwest coast of India, and Morris and Bennett (1952) in Australia.

Materials and Methods

The life histories of organisms such as these which pass through stages characterized by great changes in appearance, size, habit and residence, must of necessity be studied by various means. The work in North Carolina has been carried on in two phases. First, during the years 1948-1951, study was concentrated on the adult shrimp population and its relation to the commercial fishery. Second, as the investigation progressed, its scope was broadened to include other phases of the life histories, and recently study has been concentrated on the juveniles. The entire investigation has consisted, in large part, of length-frequency studies with accompanying observations on the ecology of the species.

Adults. Broad (1951b) stated that from 1948 to 1951 the collected materials consisted chiefly of adult shrimps taken from commercial catches as they were landed at fish houses along the coast. Localities

rom which the catches came were established as closely as possible y questioning the skippers of the trawlers. In addition to samples rom fish houses, other collections were made with standard commer- ial shrimping gear in various localities at irregular intervals with the se of the Institute research vessel. All shrimps taken in these manners ame from two generalized areas (Fig. 1): (1) the inside waters, ounds, bays and rivers inside the long chain of barrier islands, and 2) from the outside waters, that is, from the ocean outside the barrier slands.

Most of the samples were taken during the shrimping season in pring, summer and fall from both inside and outside waters with ommercial shrimp trawls which had a mesh size of ⅞ to 1¼ in. bar nesh. The relatively few winter samples were taken chiefly by fishing rawlers working offshore in deeper waters with trawls which had a nesh size of 1 to 2 in. bar mesh.

The commercial catches were sampled by taking double handfuls f unheaded shrimps from several different locations on the heading ables when the shrimp boats unloaded at the fish houses (Broad 95lb). All individuals in small catches made with the Institute boat, nd all individuals taken by fish trawlers in winter were measured. The total length of the shrimps from tip of rostrum to tip of telson vas used as a measurement of size and an index to age, and these engths were recorded to the nearest millimeter according to species nd sex.

Juveniles. From November, 1951 through 1953, the samples con- isted almost entirely of juvenile and young adult shrimps taken from ne shallow portions of tidal creeks, bays and sounds. The collections f juvenile shrimps were made with a beam trawl. This trawl was quipped with an oak beam 1⅞ in. by 2⅜ in. by 4½ ft., and with unners made of ½ in. by 2 in. strap iron approximately 1 ft. high. The bag and cod end were made of ¼ in. bar mesh. A tickler chain vas fastened between the lower sides of the runners. The trawl was owed from a skiff powered with either a 7 ½ or a 10 horsepower outboard motor. Nearly all of the materials taken in this trawl were vashed through a set of three graduated nesting screens. This combi- nation of fine net and screens was quite efficient in straining out small organisms. All of the shrimps caught were measured in the same nanner as the adults.

The greater part of this material was taken from fixed localities. Fixed localities were deemed necessary because they formed a basis

for making comparisons among collections through the seasons, and through any successive years that the study might continue. The primary objectives of this phase of the work were to determine: (1) the location of the nursery areas; (2) which species used the nursery areas; (3) when the different species occupied the nursery areas; (4) where the various growth stages were spent; (5) species preferences in habitat; (6) the growth rates of the species. To collect this information as rapidly as possible, the survey had to cover a broad choice of ecological situations within a limited area. Fortunately, Carteret and Onslow Counties offered a broad selection of habitats at localities within a few miles of the laboratory. To accelerate the program, the sampling gear was hauled in a trailer to the several localities, and all work accomplished from rented skiffs.

The localities were further defined by establishing fixed stations in a variety of physical situations within the general locality, and by the institution of a standard tow of 200 yds. between permanent stakes at each station. The 200 yd. tow length was chosen by compromise. Tows of 100 yds. yielded what seemed to be inadequate samples, especially from stations having a hard bottom. Tow lengths greater than 200 yds. were inefficient especially at stations where fibrous peat covering the bottom caused the trawl to clog. In nearly all localities sampled for juveniles, the stations represented not only a variety of bottom types, but also a longitudinal transect of the body of water involved.

These localities are listed in Table 1 and are mapped in Figures 1 and 2. With the use of the beam trawl, localities A through L (Tab. 1) were sampled frequently, but irregularly, throughout one year; and selected localities (starred) were sampled once a month for a second year. The remainder of the localities described in Table 1 were sampled once a month during the spring, summer and fall of the second year. The latter localities were along the western shore of Pamlico Sound (Fig. 1), and were used mainly as indicators of the extent of the nursery grounds.

Plankton samples. From 1950 through 1952 and a portion of 1953, plankton samples were taken with drift nets and dredges in an effort to capture larval and post-larval stages as they entered the estuaries. One-foot nets equipped with either No. O or No. 2 silk bolting cloth were used in taking plankton samples, and a dredge equipped with No. 2 silk bolting cloth was used in taking bottom samples. Most of the plankton samples were obtained by 15 min. tows from bridges

FIGURE 2. Map of Carteret County, North Carolina with portions of Onslow, Jones, Craven and Pamlico Counties and associated coastal features. Inset at lower right hand corner shows extension of Core Banks. White letters on solid circles indicate localities from which samples of juveniles were taken from 1951 to 1953 (see also Tab. 1).

TABLE 1.

A summary of environmental observations at localities and stations where juvenile shrimp were regularly collected. Localities marked with an asterisk (*) were sampled for two consecutive years.

Localities	Stations	Bottom Types	Depth Feet	Cover	Tidal Action	Bottom Sal. Winter ‰	Bottom Sal. Summer ‰	Annual Bottom Temp. Range °C.
A.* Queen Creek, 3 mi. SW Swansboro, Onslow Co.	1. Mouth of Hall Creek	Soft mud & Shellbar	2	Algae	Weak	18.8-29.4	16.4-34.5	9.6-32.8
	2. "North Side Channel"	Hard Clay	8	None	Strong	24.0-28.0	29.3-35.0	9.4-31.4
	3. Great Neck Landing	Sand	8	"	"	26.2	31.9-34.9	9.0-31.2
	4. North mouth of Queen Creek	"	8	"	"	26.9-30.3	32.2-35.3	8.4-30.8
B.* White Oak River at Stella, Carteret Co.	5. "Lone Pine"	Mud	5	Forest debris	Mod.	Fr-16.6	12.3-21.5	7.0-30.4
	6. "South Ditch"	"	15	" "	"	Fr-14.3	17.8-36.1	6.6-30.0
	7. Bridge at Stella	"	12	" "	"	Fr-09.8	10.2-18.4	6.8-30.8
	8. Mouth of Hunter Creek (Intermittent)	Hard Clay & Mud	15-20	" "	"	Fr	6.1	10.2-28.0
C. Pettiford Cr., 2½ mi. SE Peletier, Carteret Co.	9. Whiteoak River at mouth of Pettiford Cr.	Hard Clay & Mud	2-5	Algae	"	22.1	27.1-32.7	11.2-31.0
	10. "Headland"	Mud	3	Forest debris	"	17.9	23.2-31.0	11.6-32.4
	11. Upstream on Pettiford Cr.	"	6	" "	"	Fr	10.8-19.2	10.8-32.8
D. Broad Cr., 12 mi. W Morehead City, Carteret Co.	12. Inland Waterway at mouth of Broad Creek	Sand	12	None	Weak	28.9-29.3	30.6-35.7	10.0-29.4
	13. Broad Creek Bridge	Mud & Shell	2-5	Algae	"	29.1	30.1-33.2	13.0-31.8
	14. Upstream on West Prong	Mud	2-4	Forest debris	"	24.5-25.9	25.5-34.2	14.0-32.4
E.* Tidal Basin near Atlantic Beach, Carteret Co.	15. "Basin Mouth"	Hard Clay	2-5	None	"	17.0-33.0	33.9-37.2	7.8-29.0
	16. West end of Basin	Mud	2	Algae	"			
F.* Newport River, 2½ mi. N Morehead City, Carteret Co.	17. Off Lawton Point	Soft Mud	4-6	None	Strong	12.9-26.9	26.0-34.9	7.8-30.4
	18. Above Cross Rock	" "	2-4	"	"	11.1-20.3		11.0
	19. Mouth of Newport Narrows	Mud	6	Forest debris	"	Fr-19.4	11.3-32.9	6.8-29.2
	20. "Diagonal Channel"(Interm.)	"	12	" "	"	Fr-15.5	Fr-32.4	8.4-29.6

G.* Adams Creek, Carteret Co.	21. Inland Waterway near #22	"	12	" "	Weak, with wind tides	12.8-20.8	16.3-28.9	9.8-23.8
	22. Cedar-Jonaquin Crs. mouth	"	4-6	" "			15.2-28.9	31.4
	23. Jonaquin Thorofare	"	7	" "		11.3	15.9-18.7	12.8-32.6
	24. Upstream on Cedar Creek	Fibrs. Peat	3	" "		5.6-11.0	15.1-27.8	7.0-35.0
H. South River, Carteret Co.	25. Middle, South R. near #26	Mud & Clay	12	None	Wind tides	13.8	14.4-20.5	10.6-31.2
	26. Mouth of Big Creek	" "	8	Forest debris		13.9	13.9-16.5	10.8-31.4
	27. Mouth of Savannah Creek	Fibrs. Peat	3	" "	"	14.2	13.6-16.5	11.0-31.4
	28. Upstream on Big Creek	" "	2-3	" "	"	12.0	12.8-14.4	11.4-32.2
I.* Williston, Carteret Co.	29. Wade Creek	Clay & Sand	2-3	None	Weak	19.1-25.5	31.7-36.2	6.8-31.4
	30. Jarrett Bay near Howland Cr.	Hard Clay	3	"	"	24.9-26.0	27.2-36.0	6.8-31.2
	31. Williston Creek Bridge	Soft Mud	3	Refuse	"	19.4-25.0	27.4-36.2	6.6-30.2
	32. Upstream on Williston Cr.	Fibrs. Peat	3	Forest debris	"	8.8-25.1	22.8-34.5	10.6-31.2
J. Oyster Creek, Carteret Co.	33. North side, Oyster Creek	Hard Clay	3	Algae	"	25.3	26.4-35.5	14.0-30.2
	34. Near head of Oyster Creek	Fibrs. Peat	3	Forest debris	"	24.0	26.5-34.2	17.8-31.8
K.* Lewis Creek, Cedar Island, Carteret Co.	35. Core Sound near Lewis Cr.	Sand	4	None	"	28.8	25.9-35.9	29.2
	36. Lewis Creek at Fish House	Mud	3-4	Algae	"	25.6	24.3-33.8	13.2-30.0
	37. Near head of Lewis Creek	Fibrs. Peat	1-2	None	"	23.9-25.6	23.8-32.4	10.0-32.0
L.* Core Sound, Carteret Co.	38. Various places on broad shoals and in sloughs	Sandy Mud	1-6	None in winter Veg. in summer	"	Sal. has complex annual range Temp. has complex annual range		
M. Smith Creek, Oriental, Pamlico Co.	39. Mouth of Smith Creek	Hard Clay	3	None	Wind tides		9.0-16.1	30.0
	40. West Branch, Smith Creek	Soft Mud	1-2	Forest debris			8.9-14.4	31.1
	41. Upstream on Smith Creek	Fibrs. Peat	6	" "	"		8.2-14.6	32.2
N. Gale Creek, Trib. Bay River, Pamlico Co.	42. Ind. Watwy., Gale Cr. Mouth	Hard Clay	12	None	"		11.6-16.1	30.0
	43. Mid-section of Gale Creek	Mud	6	"	"		11.8-15.7	25.6
	44. Near Gale Creek Bridge	Fibrs. Peat	2-3	Forest debris	"		11.0-16.2	31.7
O. South Creek, Beaufort Co.	45. Muddy Creek	Mud & Shell	2-3	" "	"		6.4-11.8	31.7
	46. Off Gum Point	Hard Clay	2-10	Vegetation	"		6.3-11.1	31.7
P. Rose Bay, Hyde Co.	47. Upper part of Rose Bay	Mud	7	None	"		9.6-16.7	30.0
	48. Rose Bay Creek	"	7	Forest debris	"		9.6-14.9	
	49. East branch, Rose Bay Cr.	"	7	" "	"		8.4-14.5	30.6
Q. Far Creek, Engelhard, Hyde Co.	50. Near channel marker #3	"	7	None	"		17.9	28.4
	51. White flash night beacon	"	6	Town refuse	"		15.3-18.8	28.9
	52. Far Creek in Engelhard	"	6	" "	"		15.8-18.3	29.5

or piers in the Beaufort Inlet area wherever tidal currents would cause the nets to stream. Dredge hauls were made at scattered localities.

Gonad inspection. At irregular intervals during 1951-1952, and throughout 1953, attempts were made to establish the time and place of spawning for each species by inspection of the developmental state of the gonads. Gross determinations of the sexual development of shrimps were made as catches were landed at fish houses. The results of this work are not yet completely evaluated, although certain facts are presented.

Physical environment. Systematic environmental observations were recorded only at the stations established for juvenile collections. A summary of these observations is given in Table 1. Only the intensively sampled localities are recorded in this table, and the chief purpose of the table is to provide a terse description of the environments found in the areas sampled.

Salinities were determined by the use of hydrometers and correction tables. Bottom temperatures and salinities were recorded only from June 15, 1952, through 1953. Prior to that time it was erroneously assumed that in shallow creeks and bays (1 to 6 ft. deep) there would be little or no difference between surface and bottom salinities. Although this is occasionally true, the usual case is quite different, for even in depths of less than 3 ft. there is often a marked vertical gradient in salinity and temperature.

Hydrogen-ion concentrations were taken from surface samples. These determinations were made with a Hellige Hydrogen Ion Comparator which was checked against a Beckman pH meter from time to time.

Statistical Treatment

Comparisons of length-frequency distributions for adult male and female shrimps from 1948 through 1952, and for juvenile shrimps from 1951 to 1953, are given in Figures 3-8, using sample comparison diagrams. In each of the graphic figures, the range of variation is represented by the vertical line, the mean is shown by the horizontal line, one standard deviation on each side of the mean is indicated by the hollow rectangle, and twice the standard error on each side of the mean is represented by the solid rectangle. The number of specimens in each sample is shown adjacent to the vertical line. A significant difference between paired samples is indicated if the black rectangles overlap by one-third or less the length of the shorter of the two rectangles. In the paired samples of male and female adults this

graphic method is used both to describe each sample fully and to show the differences in total length between the males and females. In the case of juveniles, the method is employed to describe each sample and to demonstrate growth trends in the population. The method is not intended to demonstrate statistical significance in growth rates nor to compare closely the samples in successive years.

Adults. The length-frequency information on adults was collected over a period of approximately five years. Inasmuch as the program depended heavily on the erratic movements of the commercial fleet, the sampling was not random. Compounding these difficulties were the different mesh sizes used in the commercial trawls, and some unavoidable lapses in collecting the data. Nevertheless, the program was carried on over a number of years, and during this time a considerable body of information was obtained.

As the work on juvenile shrimps progressed, it seemed desirable to extract as much information as possible from the earlier body of data on adults, and to link it with the results of the work on juveniles. This information is embodied in the life histories as outlined below, but certain reservations concerning the statistical treatment must preface the life history accounts.

The annual adult population trends for each of the three species of shrimps were established by Broad (1951a). The number of adults (sexes separated) measured monthly are shown in Table 2. The figures show that the heavy fisheries occur during the spring, summer and fall. With the qualified exception of 1949, no year has a complete series of samples. (The samples for 1952 were collected incidental to other work and for the greater part are not representative.)

It would be desirable to compare statistically the mean lengths of samples from different years, month by month, in order to determine whether the sizes of shrimps differ significantly between years. In a series of measurements taken over many years, the measurements might be averaged month by month, in a manner analogous to monthly temperature records for a given locality over a period of years. The data at hand, however, consist of relatively small discontinuous samples from the relatively short period of five years and thus preclude such treatment. Unfortunately, among the few samples that could be compared, results were inconsistent. The nature of the inconsistencies demonstrates the fact that the samples were not representative. Inequality of sample size makes comparison difficult in some of the months, but one of the chief difficulties in these comparisons is a lack

TABLE 2.

Adult shrimp samples 1948-1952. Males and females are listed separately in each month.

Year	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Penaeus setiferus																								
1948															76	88	284*	287*	214*	266*	28	21	13	19
1949	17	23	4	10	1		29	29	43	83	14	13	6	15	39	37	75*	103*	9	15	112	131		
1950												1	62†	65†	39	36	223*	221*	122*	124*	5	6	13	
1951	2	1			1	1																		
Penaeus duorarum																								
1948																							15	33
1949	19	45	2	5		3	33	29	46*	35*	1352*	1378*	162*	89*	70	61	54	48	45*	41*	33	47		
1950											407*	459*	322*	239*	12	9	44	54	26*	22*	18	10		1
1951	33	77	9	19	15	37	362†	186†	242*	231*	14	25												
1952					41	45	87	87	108*	74*	36	45												
Penaeus aztecus																								
1948															281*	380*	119†	148†	16	20	38	52	26	14
1949	12	18		4			6	8		1	679	641	955*	881*	600*	734*	292†	308†	167	128	259	271		
1950											47	29	418*	362*	460*	441*	34	51	67	73	65	75	7	6
1951				1							80	46												
1952									35†	35†														

* These samples were treated statistically for comparisons between years (see text.).
† These samples are comprised of single collections, hence they are known to be biased.

of continuous sampling from definite localities. For example, *Penaeus aztecus* individuals in samples from bays near the mouth of the Pamlico River on a given date are usually smaller than individuals in samples taken on the same day from the middle of Pamlico Sound or from near Ocracoke Inlet. Samples containing a predominance of individuals from the bays on the northwest shore of Pamlico Sound on a given date in one year cannot be compared with samples containing a predominance of individuals from other areas on the same date in succeeding years. No attempt has been made, therefore, to demonstrate size differences between years.[2]

Regardless of the chance for error, the five-year data for each of the species were summed on a monthly basis in order to form a body of information that was accordant with the results from the studies on juveniles. Though lacking a statistical basis, there are two facts which support this treatment. First, each of the three fisheries occurs in an approximately identical sequence annually. This suggests that the maturing shrimps must be nearly the same size each year. Second, there is a close relationship between the growth data from the juvenile shrimps and the measurements of the adults.

Weymouth *et al.* (1933) recognized a disparity in the mean total lengths of the sexes which increased with age in *Penaeus setiferus* When the sampled population reached a mean total length of 130 mm. the size disparity became evident, and in their graphs there is clearly a difference in the 140 - 150 mm range of mean total lengths. Other authors have noted a disparity in the sizes of the sexes as maturity is approached in this and other species of penaeids. This growth characteristic holds true for the three species in North Carolina; therefore, the sexes were treated separately to refine the adult length-frequency measurements as much as possible.

Juveniles. The survey of juvenile shrimps in nursery areas was planned to extend for two or more years. One of the first difficulties encountered in this work was identification of the juvenile shrimps, for although morphological differences were well established for late juvenile shrimps, no clear-cut or rapid methods of identification had been demonstrated for early juvenile stages. Satisfactory methods of identification were gradually established and used in routine identification of juveniles (Williams, 1953).

Comparisons of samples taken from fixed localities in successive

[2]The starred numbers within species in Table 2 have been compared, and the raw data are on file at the Institute of Fisheries Research.

years were readily accomplished, but associated with these comparisons was the question of whether the juvenile shrimps of each species in the area comprised one large population or whether each major estuary had its distinct population. Samples collected from the several localities within short periods of time, usually one week, were compared by the graphic *t*-test described above. With two exceptions there was no significant difference in mean total lengths. (An example of a locality comparison is given in Table 3 in which the measurements for the sexes are listed separately.) The two exceptions can be attributed to local environmental situations. First, the White Oak River is a locality which has widely fluctuating but generally low salinities. Juvenile shrimps at certain seasons, are very numerous in this place, and predominantly small. Whenever this locality was included in a weekly sample, the effect was a depression of the weekly mean. Second, Lewis Creek, which is in reality an arm of Core Sound in a region of relatively high salinity near Drum Inlet, contains a sparse population with a preponderance of large juveniles. Whenever this locality was included in a weekly sample, the effect was a slight elevation of the weekly mean. It was concluded that for each species in the area studied, there is a single large population of juveniles which manifests local variations in mean total length.

TABLE 3.

Comparison of mean total lengths in millimeters of juvenile *Penaeus aztecus* from five localities in Carteret County during the week of June 8-14, 1952.

	Males				Females			
	No.	Mean	S.D.	S.E.	No.	Mean	S.D.	S.E.
Queen Creek	26	63.5	17.1	3.4	27	69.7	21.1	4.1
Pettiford Creek (Trib., White Oak R.)	36	65.9	16.9	2.8	27	63.7	22.4	4.3
Newport River	31	68.6	21.4	3.8	41	68.1	21.1	3.3
Oyster Creek	32	62.4	16.2	2.9	25	61.7	20.2	4.0
Lewis Creek*	15	59.3	15.1	3.9	11	78.5	14.5	4.4

*Males and females in this small sample show a difference in mean total length which is significant at the five per cent level. Such a difference among juveniles may be attributed here to the small sample.

The sexes were not analyzed separately in the statistical treatment of the juveniles. Repeated *t*-tests of samples showed that no significant difference between mean total length of males and females of the

specific populations exists until the mean size of the shrimps exceeds 100 mm. None of the juvenile populations exceeds this mean size.

Post Larval Life Histories

Results of plankton tows. The penaeids captured in plankton tows and a few dredge hauls in the Morehead City-Beaufort vicinity were almost exclusively post-larvae. No difference was noticed in the number of individuals taken on flood as opposed to ebb tide; however, a great difference was noticed in the total catch at the Institute pier (4½ mi. west of Beaufort Inlet) and in the catches from other stations farther inland. The usual result at inland stations, up to 10 mi. from Beaufort Inlet, was no post-larvae, but at times up to five post-larvae were taken during 15 min. tows with a one-foot net. Tows for the same length of time at the Institute pier yielded up to 75 post-larvae. Few larval stages were taken in these tows. Pearson (1939) and Heegaard (1953) give accounts of egg and larval stages taken in plankton hauls in and near inlets.

The nature of these catches suggests that the post-larvae are not pelagic but benthonic (Anderson *et al.*, 1949), and that only in regions of great turbulence are post-larvae regularly found off the bottom. The survey also shows that there is a seasonal fluctuation in the abundance of planktonic post-larvae. Post-larvae are sporadically abundant in plankton catches from March to October. They are least abundant or entirely missing in plankton catches from November through February. The periods of abundance occur immediately prior to and during the periods of active recruitment of juvenile shrimp to the three specific populations; and the evidence indicates that in North Carolina the young enter the nursery areas from the sea as post-larvae, as has been amply demonstrated for other areas by numerous authors.

Penaeus setiferus. Mature *P. setiferus* occur in the Cape Fear and Carteret County regions each spring. In the Cape Fear area, a quite limited fishery for a mixture of *P. setiferus* and *P. duorarum* is maintained throughout the winter. According to fishermen there, this fishery is located off the cape, but as spring approaches, the large *P. setiferus* move inshore. During winter, the latter are reproductively inactive, but in spring the females develop a conspicuous roe coincident with the inshore movement. This occurrence is regular enough to be predictable, and the movement occurs about the first of May each year. The occurrence is less well known in the Carteret County area, but during June, 1953, and with decreasing frequency into the sum-

mer, numerous sexually mature male and female *P. setiferus* were caught in the littoral zone of the ocean and in the estuaries. A similar run of less mature adults was observed in the first part of May, 1954. The degree of sexual maturity was based on gross examination of gonads after the manner of King (1948).

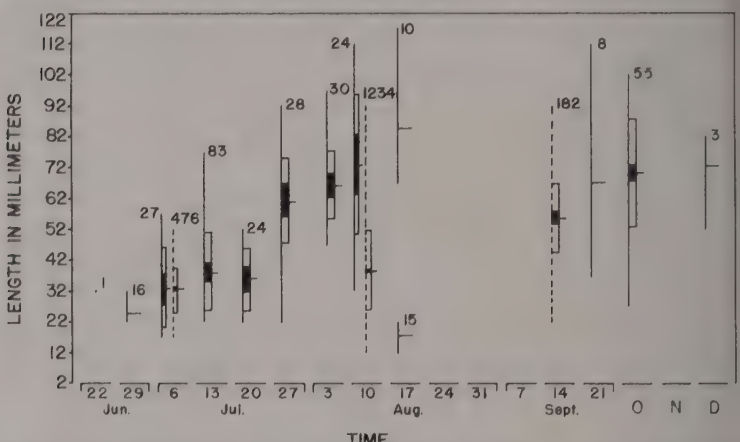


FIGURE 3. Length-frequency distributions of juvenile *Penaeus setiferus* samples from North Carolina estuaries. Samples with solid range of variation lines taken from Carteret County waters in 1951-52. Samples with broken range of variation lines taken from Engelhard in 1953 (see also Tab. 1). Numbers show size of samples. Time scale based on 1952 calendar.

The earliest recruits to the annual population of *P. setiferus* are judged to arrive in North Carolina coastal waters in June. They are presumed to arrive as post-larvae. The exact time of arrival is uncertain because post-larval species identifications have not been clearly established. Juveniles were found from late June through the summer of 1952, and from early July through the summer of 1953 (Fig. 3). To account for the summer population of juveniles, it seems reasonable to postulate that the adults were spawning during May and later, and following larval development the post-larvae moved inside the barrier islands to the nursery grounds. The presence of large sexually mature adults close inshore and within the estuaries suggests that spawning of this species may occasionally occur in these places, but direct evidence of such is lacking.

The time and place of breeding of *P. setiferus* has been treated in

the life history summary by Anderson *et al.* (1949). According to them, the breeding season in Louisiana extends from March to September, and although adults occasionally spawn near shore, spawning usually occurs in deep water. Heegaard (1953) reported spawning six miles from shore in water 10-15 fathoms deep, but editorial notes in his paper suggest that actual spawning may occur even farther from shore.

The distribution of the juvenile population of *P. setiferus* between Onslow and Hyde Counties is not uniform. In fact, during the first summer of the investigation when work was confined to the Onslow-Carteret County area, it was difficult to understand how a substantial late summer and fall fishery for *P. setiferus* could develop from the meager population of young in the area. These numerical conditions held for the young adult shrimp as well. However, during the second summer of the investigation when the work was extended to the western shore of Pamlico Sound, a dense population of *P. setiferus* was found in the Far Creek vicinity near Engelhard, Hyde County (Fig. 1). Except for scattered individuals, no other concentration was found either north or south of the Engelhard district. This group of shrimp appeared concentrated enough, together with the scattered individuals which may cover a considerable portion of the near-shore sound waters, to support the limited *P. setiferus* fishery that exists in Pamlico Sound in late summer (Broad, 1951a).

The period of recruitment, as shown by the minimum sizes in Fig. 3, extends from June to late August or September with perhaps two peaks, one in early June and one in mid-August. Gunter (1950) has shown that *P. setiferus* in the Gulf of Mexico may have two peaks of spawning, one in the spring and one in the fall. The available information suggests that the spawning season in North Carolina is more restricted than that in the Gulf of Mexico.

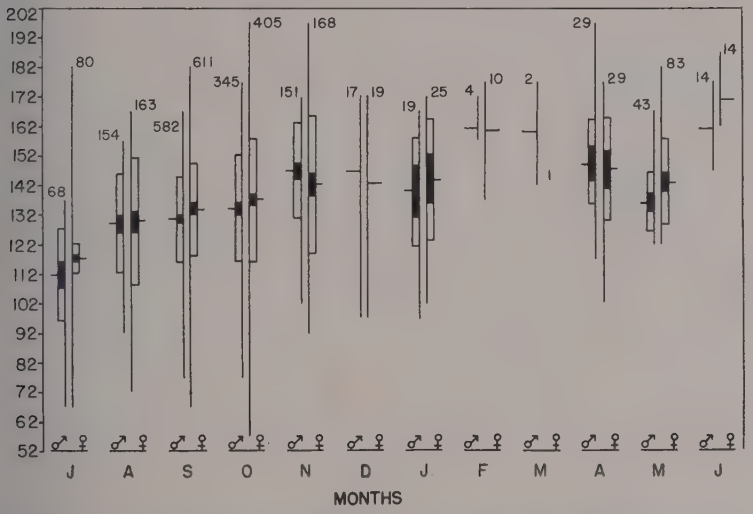
Growth of the young is rapid. From the 1952 samples (Fig. 3) it appears that juveniles which averaged 24.8 mm in length in late June were large enough to be taken commercially by late July or August (Fig. 4). The mean total lengths of the samples cannot be used as an index to growth rate because they are depressed by recruitment, but an estimate of the growth rate may be made from the progressively increasing maximum sizes. The individual measuring 32 mm total length in the week of June 22 could measure 117 mm or more by the week of August 17. Although the growth rate is not uniform from post-larva to young adult, on the basis of these data we can estimate

the growth rate at 9 mm per week, or 36 mm per month. This rate o growth agrees with that deduced by Gunter (1950) and is judged t be more nearly correct than some older estimates.

One danger inherent in using the largest individuals as the basis fo an estimate of growth rate lies in the fact that occasionally adul shrimps enter the nursery areas and are taken in the beam traw samples. These cases are self-evident, and such specimens have bee deleted from the samples.

Samples during the first year of work were small but fairly con tinuous (Fig. 3). Although there were some small samples taken fro the same area in the second year, it is more informative to show th large samples of Hyde County material in comparison with th Carteret-Onslow County material. Although the second and third Hyde County sample means are far below those of the Carteret Onslow County area, there is every indication that the onset and duration of recruitment and the rate of growth are the same in both areas. Certainly there is a difference in the density of the populations The disparity in sample size makes further comparison difficult.

The summed monthly catches of adult *P. setiferus* for a five-yea period are discussed by Broad (1951b), and are shown in Figure 4. The sample ranges of variation are great in the summer because during that season large adults are often found near shore and in the estuaries along with late juveniles or young adults. It is apparent (Figs. 3 and 4) that July is the first month in which the young of the year enter the commercial catch. Young adults continue to enter the sampled commercial catch until October (Fig. 4), and this entire process is forecast by the nature of the juvenile population. By November, the individual sizes of the shrimp and the monthly sample means have reached a level which remains essentially static through the remainder of the yearly cycle. The population is apparently sparse through the winter and spring. Most of the individuals recorded were taken from offshore waters. Occasionally in winter large schools of shrimp are found near shore. On January 4, 5, and 6, 1954, a total of 200 boxes (20,000 lbs.) of headed *P. setiferus* adults were taken in the littoral zone off Ocracoke Inlet. Such occurrences are rare, but they have been reported in the past. The time of occurrence of the *P. setiferus* fall fishery in North Carolina agrees well with that recorded by Weymouth *et al.* (1933) for Georgia, Florida and Louisiana; by Gunter (1950) for Texas; and with the occurrence of an adult specimen known from lower Chesapeake Bay in October.



IGURE 4. Length-frequency distributions of adult *Penaeus setiferus* samples om North Carolina estuaries. Measurements of males and females from 1948 1952 are summed separately on a monthly basis (see also Tab. 2). Numbers ow size of samples.

A subject for conjecture has been furnished by the "suddenness" of he appearance of this species in the commercial nets in late summer nd fall, first in the northern part of Pamlico Sound and later in the ttoral zone of the ocean, especially near Southport, Brunswick ounty. Large adults are known to move sporadically from the ocean to estuaries, but in North Carolina, whole fisheries composed of oung adults are not regarded as the consequence of movements of naturing shrimp into these areas from nursery areas in remote localies. The data indicate that the "suddenness" of the appearance of oung adults is the result of rapid maturation of large numbers of uvenile shrimp which use the estuaries as a nursery ground and which ave been in the estuaries for two months or more prior to their ommercial appearance. The young are undetected because they live n shallow water which is not usually fished. The fall fishery is susained by growing young from the nursery grounds.

The disparity in total length between the sexes (Fig. 4) is not as learly noticeable in the *P. setiferus* samples as in *P. duorarum* or *P. ztecus* samples. Furthermore, the small samples of North Carolina naterial cannot be favorably compared with the large samples of

Weymouth *et al.* (1933) in which a clear difference in the mean total length of males and females is shown at lengths above 130 mm. For the sake of uniformity, the *P. setiferus* adult samples were graphed in the same manner as the other species treated in this paper.

Penaeus duorarum. The first recruits to the annual population of *P. duorarum* have been found in late June in collections made with the beam trawl. Post-larvae have been found in plankton tows in early June, and although their identification as *P. duorarum* is not definite it may be inferred, for, with the exception of the Engelhard region, this species predominates in the juvenile population throughout the summer. The period of recruitment is long, extending from mid-June to October, as is indicated by the minimum sizes in Figure 5.

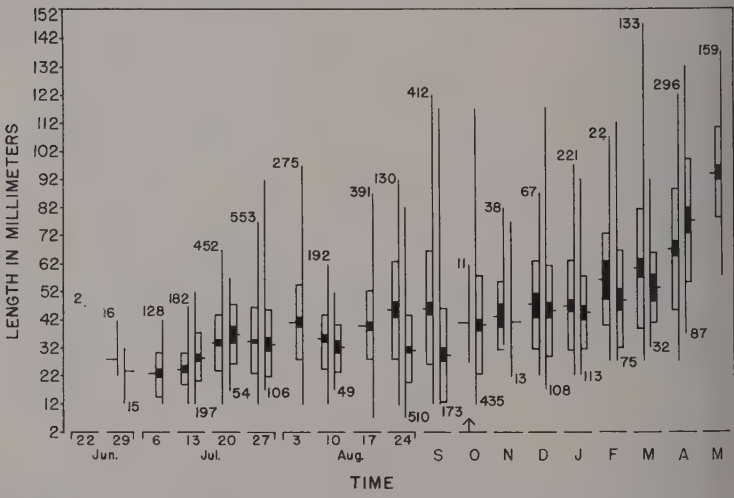


FIGURE 5. Length-frequency distributions of juvenile *Penaeus duorarum* samples from North Carolina estuaries, 1951-53. Samples with means facing left hand margin collected during first year, those with means facing right hand margin collected during second year (see also Tab. 1). Numbers show size of samples. Arrow indicates starting point of work. Time scale based on 1952 calendar.

From the rate at which growth occurs in the juvenile population (Fig. 5) it must be inferred that the young adults taken in late summer are the earliest recruits of the season which have matured. The mean total lengths of the weekly samples are not a valid basis for

estimating growth in the population, for continued recruitment to the juvenile population depresses the means. The upper extremes of the range of variation, however, give a useful estimate of growth rate of individuals. Using the first-year material as an index, a specimen 42 mm long in the week of June 29 could be 97 mm in length by the week of August 3. Growth during this five-week period, although not uniform, would average 11 mm per week or 44 mm per month. During the second year of investigation, an individual 32 mm long in the week of June 29 could have measured 92 mm by the week of July 27, a gain of 60 mm in four weeks or a gain of 15 mm per week. The mean rate of growth for the month of July in two successive years thus can be estimated at 13 mm per week or 52 per month, a considerably higher rate of growth than the 36 mm per month estimated for *P. setiferus* during approximately the same time of the year. The estimate for *P. duorarum* is judged to be the more accurate of the two on the basis of the sample sizes.

In August, the young adults enter the commercial catch (Broad 1951a, 1951b), and these individuals mingle with the few late maturing remnants from the previous year's brood. Increasing numbers of the new year's young adults are taken commercially through late summer and fall, but the fishery slows to a halt in November. By October, the entire population is composed of a heterogeneous assemblage of sizes ranging from post-larvae to adults.

A small collection of *P. duorarum* (and other species) at the Virginia Fisheries Laboratory indicates that roughly the same yearly cycle of sizes is found in lower Chesapeake Bay and its tributaries as is found in North Carolina estuaries. Juvenile *P. duorarum* in a size range from 38-50 mm were collected in September and October. Single specimens of young adults were taken in January and June. Whether the lower Chesapeake Bay and its tributaries are a nursery area is unknown, but the presence of juveniles in the fall indicates that it may serve at least as a limited nursery area.

The greater number of summer and early fall recruits do not reach maturity in the fall, but remain through the winter. During the overwintering-period growth is slower than in summer (Fig. 5), but it speeds up in the spring with the most rapid growth occurring in April and May. In the winter portion of the yearly cycle, recruitment of juveniles to the population ceases and the sample mean total lengths as well as the maximum lengths can serve as a basis for an estimate of the winter growth rate. During the first year the population had a

mean total length of 43.5 mm in November and 67.0 mm in April, or an average growth rate of 5 mm per month for the winter and early spring. If the upper extremes of the same group are used (82 mm total length in November to 122 mm in April), a mean growth rate of 8 mm per month is indicated for winter and early spring. During the second year the population had a mean total length of 41.6 mm in November and 77.0 mm in April, or an average growth rate of 7 mm per month. The upper extremes for this group were 77 mm total length in November and 132 mm in April, an increase of 10 mm per month. The mean of these four estimates is 7.5 mm per month for the colder months. The latter part of this period is a time of more active growth than the first part and by May, when high temperatures have returned, the growth rate reassumes its summer proportions.

The commercial fishery reopens about the middle of May (Fig. 6)

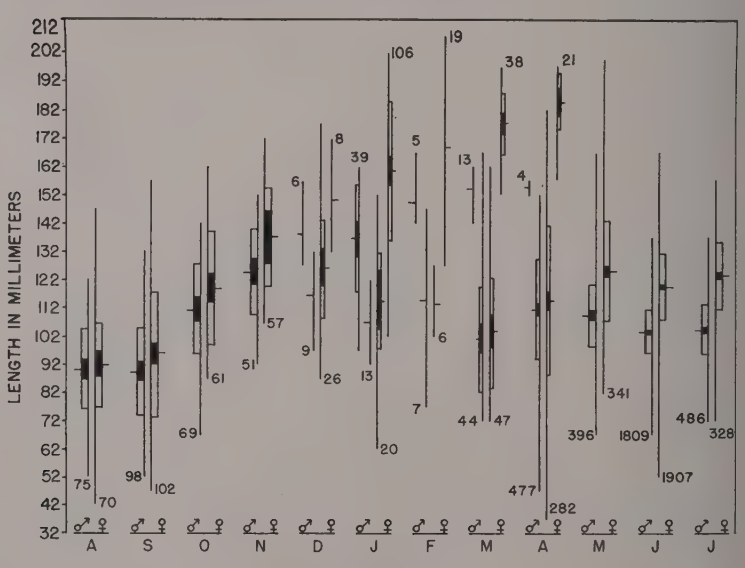


FIGURE 6. Length-frequency distributions of adult *Penaeus duorarum* samples from North Carolina estuaries. Measurements of males and females from 1948 to 1952 are summed separately on a monthly basis (see also Tab. 2). Samples from December to April are divided into inshore and offshore material; inshore material is shown in the center pair of samples, offshore material in the adjacent bordering samples. Numbers show size of samples.

and large numbers of adults are caught from then until mid-June. During May, roe-bearing females make their appearance in the catches together with maturing males, and by June the preponderance of individuals is sexually mature. During this time, the focus of fishing activity shifts from the estuaries to the littoral zone of the ocean, especially near Beaufort Inlet. The arrival of the mature shrimp in the ocean immediately precedes the appearance of post-larvae, which are the first arrivals of the new brood.

The winter catches of adults (Fig. 6) were taken from two general sources which are not strictly comparable, and for that reason, these samples have been arbitrarily broken into two groups on the basis of size and geographic occurrence. The larger specimens, which occurred in water up to 18 fathoms deep, were generally taken by fishing trawlers working offshore only in winter. This population of large adults has no representation in the collected data during the remainder of the year because there has been no opportunity to work in deep water in the spring, summer, and fall. The smaller of the wintertime individuals were taken in water near shore and are fairly comparable in size to adult samples at other seasons of the year. There is undoubtedly a mixture of the two components in these winter samples, but the bimodality of the curve for the material indicated that some distinction should be attempted.

There is a sex size disparity in adult *P. duorarum* which is statistically significant at mean total lengths which exceed 100 mm. In most of the monthly samples (Fig. 6) this difference is clearly a function of age with the females becoming proportionately larger than the males as they grow older. This difference is so clearly marked that in a catch of adult shrimps the individuals can often be sexed almost on the basis of size and body proportions alone.

Penaeus duorarum is the only penaeid shrimp which survives through the winter in North Carolina estuaries (except for occasional individuals of the other two commercial species). There is strong evidence that the population found here is endemic in North Carolina as has been suggested by Burkenroad (1949).

The beam trawl samples in winter are not comparable to the summer catches in numbers of individuals per unit area trawled (Fig. 5). At water temperatures below 10°C, the shrimp are almost completely narcotized by cold and at such temperatures, few individuals can be taken, but at approximately 15°C many more individuals can be collected from the same places, and the shrimp are much more active.

Shrimp have been collected from water with a temperature of 6°C. (Temperatures in Core Sound as low as 4°C were recorded in 1952.)

The size of samples in winter varies directly with the rise and fall of the water temperature and because such changes in temperature occur rapidly in the shallow estuaries, the size of samples changes almost daily. Such changes in catch size could be accounted for by migrations of shrimp between deep and shallow water in response to temperature changes, but the lateral distance involved in such movements would necessarily require that the shrimp in many cases move miles within a comparatively short period of time and at a time when they were nearly inactive from cold. Samples from adjacent shallow and deep areas do not show such movements. It appears more likely that the shrimp remain burrowed in the mud during periods of cold, although it has not been proved that the entire population does this. Isolated facts, however, lend considerable support to this idea. First, the beam trawl samples contain much mud and debris from the bottom. The shrimp caught in winter or summer are tangled in this mass of material. Second, oyster dredges working in the sounds in winter often dredge up shrimp from the oyster beds. Third, numerous reports by fishermen indicate that shrimp have been accidentally uncovered by raking or otherwise overturning sand along the beaches in the sounds, and on some occasions, living shrimp have been found buried in sand several feet from the water. In other instances, during periods of extremely low tides in winter, shrimp have been found in isolated shallow puddles along a muddy estuarine shore. On the basis of beam trawl samples and these reports, the evidence is clear that a large portion of the population of immature *P. duorarum* overwinters in the North Carolina estuaries.

Penaeus aztecus. The first identifiable recruits to the annual population of *P. aztecus* have been found in samples taken with the beam trawl in mid-April (Fig. 7). Post-larvae have been collected in plankton nets in February, and late post-larvae have been taken in the beam trawl in late March and early April. Although these post-larvae are too small for specific identification, there is strong evidence that they are *P. azectus,* for no juveniles of other species occur here during the early spring immediately subsequent to the appearance of these post-larvae. Recruitment to the annual population is judged to extend from late February to early June with a peak in the first half of May (Fig. 7). The minimum sizes show that limited recruitment also occurs

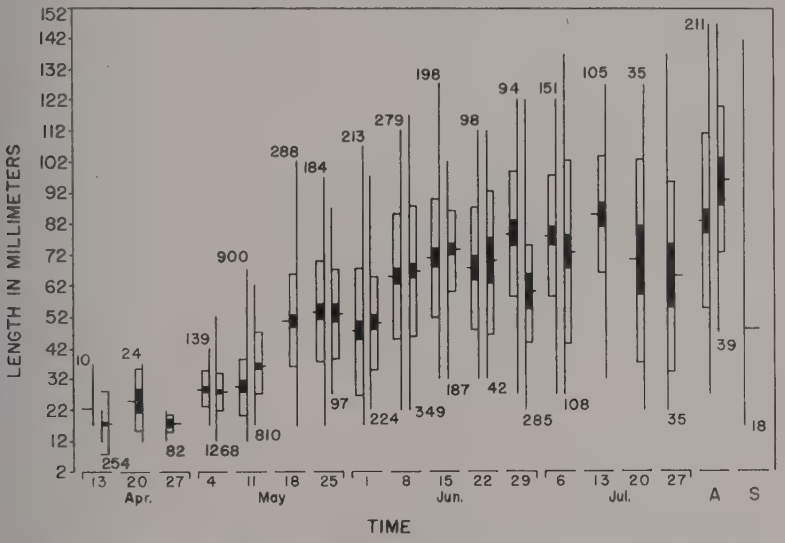


FIGURE 7. Length-frequency distributions of juvenile *Penaeus aztecus* samples from North Carolina estuaries, 1951-53. Samples with means facing left hand margin collected during first year, those with means facing right hand margin collected during second year (see also Tab. 1). Numbers show size of samples. Time scale based on 1952 calendar.

during summer. Pearson (1939) implied that the breeding season extends throughout the year, because planktonic young shrimps, presumed to be *P. aztecus,* were found along the coast of Florida and Louisiana the year around, though they were most abundant in spring and summer. Gunter (1950) indicated in a graph that this species actively recruits to the estuarine juvenile population from April to July and from September to December along the Texas coast.

The means and maximum sizes in the juvenile samples clearly indicate that growth in the North Carolina population is rapid. Because the means are depressed by recruitment, the upper extremes must be used as the basis for an estimate of the rate of growth. In samples taken during the first year, the estimated increase in size between the week of April 13 and May 18 (Fig. 7) was from 37 mm to 102 mm total length, a mean weekly growth rate of 13 mm or a monthly growth rate of 52 mm. If the largest individual in the week of May 18 is disregarded and the largest individual in the week of June 15 is considered instead, an estimated growth from 37 mm to

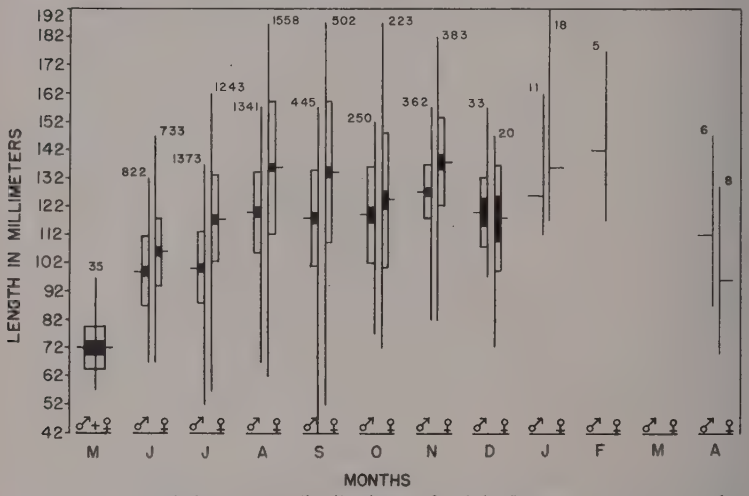


FIGURE 8. Length-frequency distributions of adult *Penaeus aztecus* samples from North Carolina estuaries. With the exception of the month of May, measurements of males and females from 1948 to 1952 are summed separately on a monthly basis (see also Tab. 2). Numbers show size of samples.

127 mm is shown. This amounts to an estimated weekly growth rate of 10 mm or 40 mm per month. During the second year, the increase from the week of April 13 to June 8 was 95 mm, 12 mm per week or 48 mm per month. The mean of these three estimates is 11.7 mm per week or 46.7 mm per month. This figure is lower than that estimated for *P. duorarum* but higher than the rate estimated for *P. setiferus* at the seasons when the young of each species are actively recruiting.

Penaeus aztecus enters the commercial fishery in June and recruitment continues until September (Fig. 8). The commercial shrimp season in North Carolina has been opened during the first half of May in recent years. During the first month of the season, nearly all of the catch is composed of *P. duorarum,* but in June *P. aztecus* young adults rather suddenly appear in catches made in the estuaries. Prior to this appearance, the young have been on the nursery grounds in the estuaries for two months or more and their extremely rapid growth accompanied by migration toward deeper water brings great numbers of the shrimp into fishable waters rather suddenly. The rapidly maturing young swell the number of individuals in the catches throughout the summer, especially in Pamlico Sound. Broad (1951a) wrote

that this fishery reaches a peak in July and August. The adult population also shows the summer recruitment by the continued low level of the minimum sizes, but with the onset of autumn the numbers of adults decrease and recruitment of young ceases. Except for occasional individuals (inshore and offshore) no *P. aztecus* are known to overwinter in North Carolina waters.

Four specimens in the Virginia Fisheries Laboratory collection show that *P. aztecus* occurs in the lower part of Chesapeake Bay from August to November. The sizes of the shrimp indicate that they are young adults and that they must be the maturing young of the year. Similar finds along the New Jersey coast were reported by Burkenroad (1939). He considered these young to be migrants which had moved north during the summer.

Penaeus aztecus, like its close relative *P. duorarum,* exhibits a size disparity between the sexes which increases with advancing age. A level of significant difference between the mean total lengths of males and females is reached at about 100 mm (Fig. 8). The size difference increases with age, and in catches of adults, the sexes may be separated almost on the basis of size and body proportions alone.

ECOLOGY

The ecology of juvenile penaeids has been variously treated by the authors mentioned in the introduction to this paper. The observations on North Carolina shrimps offer nothing unique, and in general, they concur with the findings of others.

The areas most attractive to juvenile shrimps are in shallow estuaries which have a predominantly soft bottom. Such areas may be near the ocean, or in certain cases, they are miles from the nearest inlet. The population is usually more dense in localities near the sea than in those far from the inlets, apparently because of the relative accessabilities of the areas. For instance, many more shrimp are found per unit area in "J. Oyster Creek" which is near Beaufort and Barden Inlets, than are found in "N. Gale Creek" which is approximately 30 miles from the nearest inlet. Except for the concentration of *P. setiferus* in the Engelhard district, the chief known nursery areas are in estuaries extending from the Bogue Inlet vicinity around Carteret County to the Cedar Island vicinity, and in the "G. Adams Creek" vicinity (Fig. 2). "H. South River" (Fig. 2) is not a heavily utilized nursery ground. A widely distributed thin population of *P. aztecus* and scattered *P. setiferus* use the western margin of Pamlico Sound

(Fig. 1) as a nursery area, but few *P. duorarum* juveniles are found north of the Neuse River. The extent of nursery grounds on shoals of the barrier islands inside Pamlico Sound and the extent of the nursery area in the Southport vicinity has not been investigated.

Within the nursery areas a number of bottom types may exist (Tab. 1), and repeated collections show that a soft substratum of mud or fibrous peat is preferred by the young, as others have observed, but in special cases, sand or clay may provide a satisfactory substratum. The young are not attracted to bare clay, sand or shell bars. Depth of water over such areas has no observed effect on the density of the population, although by the very nature of the preferred areas, the water is usually quite shallow.

Within preferred areas, though, other factors modify population density. Observations show that availability of cover is one of the most essential requirements for a satisfactory nursery area. The types of cover available vary somewhat with the substratum and the salinity as well as with the geographic position. In brackish creeks which run through the marshes and have their headwaters in either pocosins or well-drained forested areas, there is a great quantity of forest litter scattered over the bottom. This material, in various stages of decomposition, affords one type of favored habitat. Another type of cover is provided by living vegetation. Over such areas as the broad sand or clay shoals in Core Sound, where there are hundreds of acres of the marine "grass" *Diplanthera Wrightii* mixed with some *Zostera marina*, the juvenile shrimp population is enormous. However, in the deeper portions of the sound and wherever the ground lies bare on the shoals, the population is almost nonexistent. Other plants which are associated with the young in a minor way are Gracillaria where it occurs on soft bottom. Other estuarine plants such as *Codium, Hypnea,* and *Ruppia maritima* ordinarily do not afford a good cover for juveniles.

Availability of food in the nursery areas is of paramount importance to the population, and the preferred types of bottom and cover while easily appraised as important, are undoubtedly associated with an abundant food supply. The shrimp are bottom feeders. There is general agreement among investigators that juvenile and adult shrimp eat any available organic material.

During the fall and winter of 1952, the stomachs of 184 adult and young adult shrimp from the estuaries were examined for amount and kind of contents. During the fall the stomachs were usually found to be full or half-filled, but in the winter the stomachs were nearly always

empty. Gross examinations of shrimp in summer showed that stomachs and guts were usually filled. The material in the stomachs was finely triturated and in most cases, difficult to identify.

The most abundant materials in order of decreasing frequency of occurrence were: (1) usually a mass of unrecognizable debris, probably a mixture of digesting tissue and organic deposit from the bottom; (2) chitin fragments, obviously from crustacean species but none identifiable; (3) setae, apparently from annelids; (4) annelid worm jaws; (5) plant fragments; (6) sand. Other materials occurring in varying quantities were: foraminifera; minute gastropod and lamellibranch shells; squid suckers; complete small fishes; fish scales; muscle fibers, gut, mandible, ribs, eye lens; unidentified eggs; plant seed pods; fibers with a piece of brass attached. Most of the materials, except the muscle fibers and unrecognizable debris, are hard. Although they indicate types of food that the shrimps eat, they are too hard to be triturated easily and, because large fragments will not pass through the straining apparatus in the pyloric stomach, hard parts may accumulate in quantity in the stomach. Whether most of these hard materials are further broken down for alimentation or are regurgitated is not known, but unrecognized softer and more easily digested materials could easily form the bulk of the diet.

Many of the estuarine nursery areas in North Carolina are in regions of weak tidal action or are inland in regions beyond the influence of periodic tides. Although most of the dense juvenile populations occur in areas where there is some daily tidal action, at least one dense population (*P. setiferus* at Engelhard, Hyde County) occurs far from the nearest inlet in a region of no regular tide. Moreover, a large portion of the juvenile population which is best characterized as "scattered" is distributed over estuaries not subject to regular tidal influence. Because post-larvae are regular members of the estuarine plankton only in regions of turbulence near the inlets, it must be concluded that in relatively quiet water the young shrimps disperse themselves entirely by their own movements. During post-larval and early juvenile stages, the shrimps are able to move many miles in search of suitable nursery areas. Juvenile shrimps which utilize the western shore of Pamlico Sound as a nursery ground, must journey at least 20 to 30 miles from the nearest inlet, and tidal currents presumably could carry the young only a portion of this distance.

It is well known that the smallest juveniles of American commercial penaeids occupy the fresher portions of the nursery grounds. As

growth ensues, progressively larger individuals are found nearer the sea. Gunter (1950) has reviewed his own observations and those of others on size distribution in relation to salinity among *P. setiferus*, *P. duorarum*, and *P. aztecus*. He found, as did Burkenroad (1934), that there is an apparent positive correlation between size of shrimp and salinity. Furthermore, these workers found indications that *P. setiferus* juveniles prefer or perhaps tolerate lower salinities than do other penaeid species. My own observations confirm this suggestion, but again, the distinction is not clear cut.

The observations on surface pH were discontinued after the first year of juvenile studies. The range of pH in estuaries is ordinarily small except for upstream waters of low salinity in times of little rain during winter. Judged from observational data, surface pH is not a determining factor in the distribution of juvenile shrimps.

One important factor which was not discussed in the specific life history accounts is the nature of competition among the species for nursery grounds. The three species all use approximately the same nursery areas, but the times of recruitment of young and the periods of occupation of these areas are apparently divided among the species so that at no time do large numbers of more than one species occur together. During spring juvenile *P. aztecus* are in possession of the tidal creeks, shallow bays and sounds, the smallest individuals being in the less saline parts. At this same time nearly all of the overwintering crop of *P. duorarum* are in late juvenile or early adult stages and are in deeper water. In summer, the situation is reversed and by the time the last of the spring *P. aztecus* are leaving shallow water, juvenile *P. duorarum* are entering it. There is a mixture of the three species in nursery areas during the summer but it is composed of the lingering summer *P. aztecus* recruits, the increasing and predominant summer *P. duorarum* juveniles, and an uneven population of *P. setiferus* juveniles. Concentrations of the latter occur in regions of relatively low salinity, chiefly at Engelhard, but also in a minor way in the Newport River Narrows near Morehead City and in the White Oak River Narrows (Fig. 2). Wherever these concentrations occur, few individuals of other species are present.

It is impossible to state with certainty the degree and character of competition for nursery grounds occuring among the species. *Penaeus duorarum* and *P. aztecus* which might compete directly, occupy the grounds at different times of year, for the most part, and *P. setiferus* apparently has slightly different hydrographic requirements that

permit it to use nursery areas farther inland. It appears that there is more competition between juvenile and young adult *P. setiferus* and the other two species than there is between the latter.

ACKNOWLEDGEMENTS

Research on shrimps of commercial importance in North Carolina was initiated in 1948. The early history of these investigations has been given elsewhere (Ellison, 1948; Broad, 1950). The information presented here is the product of the efforts of a number of people. Mr. W. A. Ellison, Jr., Director of the Institute, gave guidance and counsel throughout the course of the investigations. The work from 1948 to 1951 was done by Mr. Carter Broad with the help of M. Horace Loftin, Jr., and Dr. William Sutcliffe. The sampling gear used was constructed by Mr. John G. Wegener of the Institute staff. The manuscript has been reviewed by Dr. Waldo L. Schmitt and Dr. Fenner A. Chace, Jr. of the U. S. National Museum. The Virginia Fisheries Laboratory kindly loaned specimens for study.

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The degree of comprehensiveness of the bibliography is to a large extent dependent upon the cooperation of workers in the Marine Sciences of this area. *It is therefore hoped that individuals and organizations will aid by sending copies of all relevant publications to the Editor.* Any omissions brought to the attention of the Editor will be included in subsequent issues.

It has been found convenient to use a modification of the classification used by the Journal du Conseil Bibliography for present purposes.

The Editorial staff wishes to acknowledge the valuable assistance given by a number of investigators in compiling the bibliography.

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